INDIAN MINING

A Concise Handbook for Laymen and Specialists

By J. A. DUNN, D.Sc., M.Aust.I.M.M., etc.,
Superintending Geologist, Geological Survey of India ;
Controller, Mica Production Section, Bihar

CALCUTTA :
THE MINING, GEOLOGICAL AND METALLURGICAL INSTITUTE OF INDIA
1943

Published by the Mining, Geological and Metallurgical Institute of India,
27 Chowringhee, Calcutta.

Printed in India
by G. E. Bingham, Baptist Mission Press,
41A Lower Circular Road, Calcutta.

TO MY GEOLOGICAL COLLEAGUES, WHOSE JOB DEMANDS THE TOUGHEST LIVING IN INDIA

PREFACE

Enquiries from all parts of the country are regularly submitted to the Geological Survey of India on matters concerning the mineral industry, and it has been the writer's privilege to advise on many of these problems during the last twenty-one years. Such enquiries may be concerned with prospecting, simple methods of mining and treatment, marketing, mine valuation, royalties, taxation and tariffs. The great majority of these enquiries are submitted by laymen, both officials and non-officials, and in recent years they have become particularly numerous. It became apparent that there was a real need in India for a small book, to which the layman, interested in mineral matters, could refer.

Although this somewhat elementary book was not written for the technical mining engineer, it is hoped that, should any of the latter turn its pages, they will find something of interest outside their own particular sphere. Criticism, to which the book is undoubtedly open, will be welcomed. Perhaps the author may be accused of leading the layman up the wrong path here and there, but if so it will be a well-worn path which in retrospect the engineer may find humour in treading once more.

Except for the larger companies, much mining in India is in the hands of people trying to earn a good living from innumerable small deposits scattered up and down the length and breadth of the country. Most of them are hardworking folk, anxious to know all they can of the occupation they have assumed; some have put all of what little money they possess into their venture, and the great majority deserve all the help that we can give them.

Government officials, both in the districts and the secretariats, frequently desire information which will help them to understand problems connected with the mineral development of their districts or provinces. Much of the information in this book is written particularly for such officers.

There is a large body of people in India interested in mining shares, but mining is believed to be a risky speculation in general. There are several reasons why mining investments have been regarded as of a speculative character, requiring a high risk rate of interest. Perhaps the dominant reason is the average investor's ignorance of mining technique. From this ignorance springs the wish of many to experience the enormous and often legendary profits which a few mines have made—they are unable to judge for themselves the comparative scale of values in mining, and have only too frequently been defrauded by dishonest promoters, or the latter themselves, partly in ignorance of the hazards of mining, have raised a capital out of all proportion to the value of the particular mineral deposit. Information on this side of mining will, it is hoped, lead to a more balanced appreciation of the risks involved.

In outlining the distribution of minerals throughout the world, chapter II, the position of the countries in 1938 has been followed. It is not easy to visualise the post-war grouping of countries. It may be said that the production tonnages of the future will be different from those of the past; to some extent such a criticism is true, but the immediate increase will not be great and the past tonnages serve as a guide to the comparative volume of production of each mineral. Details of costs and prices which have been current in the past may be regarded similarly as a rough index by which minerals may be compared between each other, and it must be left to the individual to make his own estimate of likely future prices; it is unlikely that there will be a permanent revolutionary post-war jump in prices on the whole.

This book is fittingly dedicated to the author's geological colleagues who, with simply the incentive of interest in their work, have been quietly responsible for so much of India's industrial development. Geology has many branches, its roots extend down into minute scientific facts, its fruits are garnered by the investing public who may know little about it. The writer has, perhaps, been presumptuous in writing this book. Maybe it should have been written by others—by a financial man who knows little of mining

and minerals, or by a pure scientist, or by a mining man who is familiar with a specialised section of mining. But the writer believes that his instincts at heart have been always with the science of minerals; from a lad mining has been in his bones, his first job after leaving University was as an underground miner for a time in gold, then he 'packed his swag' on the tin and osmiridium fields on the west coast of Tasmania, then went a-wandering as a geologist to land eventually in India where over twenty years have been spent on almost every phase of mining geology, with occasional leave spent in visiting many mines in different countries. That has been the writer's good luck and his pleasure, and now his excuse for writing this book.

I have consulted my colleagues freely in the preparation of the MS, and have discussed certain sections with bankers, engineers and others, and to all I express my sincere thanks for their ready assistance, so kindly given, more especially to Messrs E. Pinfold, J. B. Auden, G. Barron, E. J. Bradshaw, A. Farquhar, E. R. Gee, W. Kirby, and Dr. F. G. Percival who carefully read part or all of the MS.

J. A. DUNN.

Giridih, January 22nd, 1943.

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CHAPTER I

INTRODUCTION

In India, as in most countries, the vast and growing mineral industry forms the foundation of all other industries, for it provides not only the raw materials for many varieties of marketable goods but also the machinery and tools which make possible the manufacture into saleable articles of raw materials grown from the land. Much of this great mineral industry is of a highly technical nature, many of its workers are necessarily specialised along certain limited channels, and it is difficult for the layman, and even for the technician, to be able to stand back and secure a general picture of the whole. It is the object of this book to supply such a picture of the Indian mineral industry, more particularly for the layman but also, it is hoped, for the technical man in areas of the industry outside of the latter's particular specialty. Written expressly for the layman technical details have been restricted, therefore, to a minimum.

The attempt has been made to cover as broad a field as possible and to give some outline of every aspect of this vast subject. Naturally, in describing each aspect chapter by chapter, the most difficult problem has been to determine not what to include, but what to omit. The guiding rule has been—'What are the fundamental facts which anyone interested in a mining venture desires to know apart from detailed technical advice which must, in any case, be employed?'

Laymen interested in mining include not only speculators and investors in mining shares, but also government officials who may come in contact with various phases of the mining industry. In addition, there is in India a particular and very important type of layman who, having no previous experience of mining, secures a lease of a small mining property, often taking a not inconsiderable investment risk. Such men are, in themselves, valuable assets to

India, and it is largely with the hope of encouraging and helping them in their exploitations that this book has been written. Furthermore, those who are interested also in the general development of industry in India from the political point of view may find herein some guidance towards a broader, truer, and more balanced appreciation of the resources and real significance of minerals in India.

It cannot be said that India is either rich or poor in minerals. Some of her minerals are important to the world's industry in general, but, for the size of the country, her mineral resources are about the average. Development of these minerals has been slow but sure, mistakes in working them have been made, as in all countries, but a balanced review leaves cause for satisfaction on the whole. Further development will increase rapidly in the near future, for the country has now reached the stage where abundant talent and opportunity are available together.

The chapters have been arranged according to a sequence of natural groups. Thus, chapters II and III are intended to give a broad picture of the distribution and mode of occurrence of minerals in nature; chapters IV to XV outline the various phases of prospecting, development, mining, and marketing of minerals; chapters XVI to XVIII explain how a mine is evaluated and how an investor can estimate the relative value of mining shares; chapters XIX to XXIII are concerned with various legislative and other aspects of the industry.

The introduction of occasional technical terms is unavoidable in a book of this nature, but such terms have been reduced to a minimum, and it is hoped that their meaning will be apparent from the context. It is advisable, however, to explain the precise significance of the two terms *mining* and *mineral* which form the basis of this work.

Mining is concerned with the profitable extraction of useful minerals from the Earth's crust. To the mineralogist the term *mineral* has a precise scientific meaning; it may be defined as 'a homogeneous substance formed by the inorganic processes of nature, and having a definite composition and characteristic atomic

structure'. This definition excludes mixtures, but includes pure natural gases and liquids—air would be excluded as it is a mixture, as also would petroleum as it is a mixture of several hydrocarbons, but the individual constituents of these mixtures would be accepted as minerals.

In mining, the term *mineral* has a much wider significance, and includes anything in the Earth's crust which has a market value and which is to be removed with the intention of profitable disposal. It thus embraces not only such homogeneous substances as diamonds and native gold, but also such mixtures as clay, building stones, and mineral pigments. Although the oil industry is usually considered to be distinct from the mining of minerals in general, it is grouped with the others by the geologist under the widely embracing term *the mineral industry.*

There are obvious stipulations in the above wider definition of minerals, for economic factors such as marketable value, costs and grade require consideration. The fact that the mineral extracted must have a market value therefore excludes materials excavated for such engineering projects as railway and road cuttings, borrow pits, canals, and railway, water and sewer tunnels, as the materials are not excavated for their intrinsic or profitable value. Should, however, identical materials be excavated from quarries for marketing as clay, sand, gravel and rock for use in manufacture, or, say, as road metal, railway ballast, or building material, they then become included under the technical definition of mineral. In chapter XXII the legal implications of this definition are discussed.

The economic geologist classes minerals into (*a*) metallic minerals or ores, and (*b*) non-metallic minerals. The ores include mineral aggregates from which metals may be profitably extracted. The non-metallic minerals include such materials as clays, sands, coal, oil, limestone, fluorite, talc, sulphur, mica, etc. A few ores are mined not only for their metallic content but also for other purposes; *e.g.* chromite is used not only for the extraction of the metal chromium but also as a refractory material, and, similarly, bauxite is not only the ore for aluminium but is also manufactured into refractory bricks and used for several other purposes. Although

many geologists restricted the term 'ore' to minerals from which only metal was to be extracted, such a precise application has become pedantic and, in mining, it has become useful to refer to any mineral aggregate, which requires concentration treatment before sale, as ore. Thus a deposit of fluorite may contain 30% fluorite and 70% silica, and, before marketing, most of the silica must be removed; it is useful, although not technically correct perhaps, to describe the low grade material of the deposit as fluorite ore.

In concluding this Introduction the writer would advise readers to obtain copies of Bulletins, published by the Geological Survey of India, on minerals in which they may be more particularly interested. Valuable technical information may also be obtained on a wide variety of minerals from the transactions of the Mining, Geological and Metallurgical Institute of India.

CHAPTER II

USES AND WORLD DISTRIBUTION OF MINERALS

A balanced appreciation of the relative importance of the various components which contribute to the mineral industry of India requires some picture of the uses of minerals, and of their distribution not only in India but also in other parts of the world.

Consumption of minerals is progressively expanding in all countries, and, although periods of peak production alternate with periods of depression, the peaks tend to attain ever higher levels. The centres of maximum production, also, are not stable in so far as they move from place to place as old mineral deposits are worked out and new deposits are developed.

During recent years commerce has made use of a rapidly increased variety of minerals. Of the metals, only about a dozen were used as such at the beginning of this century, whilst today more than thirty find an application either in the pure state or in alloys. It is almost difficult to realise that several of the quite common metals, *e.g.* aluminium, magnesium, cadmium, and barium, were considered to be rare early this century. But there are certain metals, *e.g.* beryllium, thallium and caesium, which are so scarce in nature that their widespread use will always be denied to the metallurgist.

The Earth is composed of minerals, but the majority of each of the elements which are used in industry constitute only a very minute fraction of one per cent of that part of the Earth's crust accessible to man. It is only when nature has concentrated these elements at particular points, in the form of mineral deposits at or near the surface, that it is possible to mine the minerals and to extract the valuable elements. The number of such large mineral deposits remaining to be found cannot be great as most of the land surface of the globe is fairly well known. The world's resources of these mineral deposits are limited, and are being depleted at a

TABLE

Relative Pre-War Mineral Production of

	India.	British Empire.	U.S.A.	U.S.S.R.	France.	Germany.	Italy.	Japan.	Other important sources.
Antimony ..	0	0[1]	0[1]	0[1]	0	0[1]	—	0[1]	China.
Arsenic ..	0	▬	—[3]	=	◇	◇	◇	◇	Sweden.
Asbestos ..	—	**C**	▬	◇	▬	0	—	▬	
Barium ..	=[2]	=	—[3]	=	—	+	◇	0	
Bauxite (aluminium ore) ..	=[2]	▬	=	=	+	—[1]	=	0	
Beryllium ..	◇	—	=	0	0	0	0	0	South America.
Bismuth ..	0	—	—	—	0	◇	0	=	Peru, Bolivia.
Borates ..	0	0	**C**	▬	0	0	◇	0	
Bromine ..	0	▬	+	—	◇	◇	—	—	
Cadmium ..	0	=	=	0	—	=	=	0	
Chromite ..	+	+	▬	◇	◇	0	0	=	Turkey.
China clays ..	—	◇	—[3]	=	—	—[3]	—	=	Czechoslovakia.
Coal ..	=	◇	◇	=	—	◇	0	=	
Cobalt ..	0	+	0	0	◇	0	0	0	Belgian Congo.
Columbite-tantalite ..	◇[4]	+	▬	▬	0	0	0	0	
Copper ..	▬	◇	+	—	0	▬	0	—	Chile.
Diamonds ..	▬	+	0	0	0	0	0	0	Belgian Congo.
Diatomaceous earth ..	0	—	**C**	—	◇	—	—	=	Denmark.
Feldspar ..	=[2]	◇	+	=	0	▬	—	=	Sweden, Norway.
Fluorite ..	0[2]	◇	—[3]	=	=	+	=	=	
Fullers earth and bentonite ..	=[2]	◇	◇	=	0	0	0	0	
Gold ..	◇	**C**	◇	◇	—	0	0	◇	
Graphite ..	=[2]	=	▬	=	◇	—[3]	=	+	Austria.
Gypsum ..	=[2]	+	—[3]	=	+	=	=	=	
Iodine ..	0	0	—	=	0	0	◇	0	Chile.
Iron ore ..	=[2]	=	+	◇	◇	—	0	—	

C : World control. + : Large excess. ◇ : Excess. = : Sufficiency.

[1] Some resources when necessary. [2] Resources can be further developed.

1.

India and the Principal Nations.

	India.	British Empire.	U.S.A.	U.S.S.R.	France.	Germany.	Italy.	Japan.	Other important sources.
Kyanite-sillimanite ..	+	+	—	▬	0	0	0	0	
Lead ..	0[1]	+	+	▬	0	▬	▬	0[1]	
Lithium ..	0[1]	✧	✧	0	=	=	0	0	Argentine.
Magnesite ..	✧	—	—	✧	0	—	0	0[1]	Austria.
Manganese ..	+	+	—	+	0	0	0	—	
Mercury ..	0	▬	+	=	▬	0	+	—	Spain.
Mica ..	C	C	▬	=	▬	0	0	▬	Brazil, Madagascar.
Molybdenite ..	0	0	C	0	—	0	0	—	
Monazite ..	C	C	0	0	0	0	0	0	Brazil.
Nickel ..	0	C	0	▬	=	0[1]	0[1]	0[1]	
Nitrates ..	—	=	—[3]	=	—	=	=	=	Chile.
Petroleum ..	—	▬	C	✧	0	0	0	0	
Phosphates ..	▬	—	+	✧	+	0	0	0	
Platinum metals	0	C	▬	+	0	0	0	▬	
Potash ..	▬	0	—[3]	✧	✧	C	0	—	
Radium ..	0	C	▬	▬	0	0	0	0	Czechoslovakia, Congo.
Salt ..	=	=[4]	=	=	=	✧	✧	▬	
Selenium ..	0	+	+	0	0	0	0	0	
Silver ..	—	✧	+	=	▬	▬	▬	=	Mexico.
Strontium ..	0[1]	C	0	0	0	✧	0	0	
Sulphur ..	0[1]	—	+	=	—	—	✧	=	
Talc ..	=[2]	=	✧	=	✧	▬	✧	✧	Norway, Austria.
Tellurium ..	0	✧	✧	0	0	0	0	0	
Tin ..	0	+	0	0	0	0	0	0[1]	Bolivia, N.E.I.
Titanium ..	C	C	0	0	0	0	0	0	Norway.
Tungsten ..	=	+	—	0	—	0	0	—	China.
Vanadium ..	0[1]	✧	—	0	0	0	0	0	Peru.
Zinc ..	0[1]	+	+	=	0	—	=	▬	Poland.

— : Deficiency. ▬ : Large deficiency. 0 : Negligible or entirely absent.

[3] Deficiency results from large consumption. [4] Occasional finds.

progressively increasing rate. At the present day mining tends to be concentrated on the larger deposits which can be cheaply and economically worked. But, as these become exhausted, it will be necessary to develop lower grade and smaller deposits until, after two or three centuries, mankind will become increasingly dependent on a few metals, such as iron, aluminium, magnesium, calcium, sodium, potassium, and silicon, the concentrations of which are almost inexhaustible. One to two hundred years will witness great changes in the availability of the minor metals, and even of such important metals as lead, zinc, and copper—particularly if the rate of consumption of these increases progressively in the future as in the past forty years.

The number of mineral species which are mined for their commercial value is large, and deposits are scattered over many parts of the world. Some countries have a great surplus in certain minerals but are deficient in others—the relative positions of the seven principal nations in 1939, with respect to the more important minerals, are illustrated in Table I. No country is entirely self-sufficient, although certain nations, such as the United States and the British Empire, may approach independence in all but a few mineral requirements. The degree of mineral independence of some countries is determined by economic factors: a country may have resources of minerals which, in competition with larger deposits elsewhere, cannot be payably mined in normal times, but which may be available in times when their economic values are increased by restriction of imports, as in wartime. This explains the fact that Europe has proved far more self-supporting during wartime than was thought possible by economists who, without a knowledge of dormant resources, base their anticipations on statistics of past production. Time is not always on the side of the blockading power in war, ingenuity may invalidate the depleting effects of time on mineral stocks, and, indeed, may eventually lead to time being on the side of the blockaded country.

In this chapter, the principal sources of some sixty of the metals and minerals used in industry are reviewed. The intelligent reader will appreciate how impossible it is for India to be ever

self-sufficient, and that, accordingly, an energetic overseas trading policy, on the principle of give and take, is eminently desirable. It is also obvious that some minerals, of which we have small resources and which under normal conditions cannot be economically worked, might advisedly be reserved for times of restricted imports, such as during war. Natural sulphur is, perhaps, a good illustration of such a mineral.

Abrasives.—Many varieties of natural abrasives are used in industry, but the more valuable are diamond, corundum (including emery, an impure corundum), and garnet.

Industrial diamonds include black diamonds, or 'carbons', and 'bort', or broken and flawed or coloured diamonds unsuitable for gems. Diamonds are used in diamond drills (generally carbons), in cutting-tools, and as dies in wire-drawing, and diamond dust is used for grinding. Most carbons come from Bahia in Brazil, and bort from South Africa.

Corundum powder is used as an abrasive, either in the loose form or bonded into grinding wheels. Emery is also made up into papers and cloths. The total annual requirements of corundum and emery throughout the world are of the order of 20,000 tons. Corundum is produced mainly in South Africa, the United States, Canada, India, Madagascar and Russia, whilst emery is obtained in Greece, Turkey, the United States and Russia. In India, corundum deposits are known in Assam, Rewah State, Madras, Mysore and Kashmir.

Crushed garnet powder is made into papers and cloths for rubbing hardwoods, leather, metals, etc. Production is very variable, up to 15,000 tons a year at the most, and confined to the United States, Japan, Spain, Canada, India and Madagascar. In India garnet has been obtained mainly from Madras, Rajputana and Bihar.

Other natural abrasives, such as grinding stones, millstones, pulpstones, sharpening hones, grinding pebbles, silica, and rubbing and polishing powders, are found in many countries, and include a wide variety of rocks and minerals. Full statistics of production

are not available, but several thousand tons of this class of material are produced each year.

The principal artificial abrasives are silicon carbide, boron carbide, and fused alumina, of which the total annual production is 70,000 to 100,000 tons.

Aluminium.—See *Bauxite.*

Antimony.—This metal is mainly required for certain alloys, particularly antimonial lead alloys used in batteries, and in babbitt metal for bearings. Antimony is also required for munitions purposes, and for the manufacture of certain chemicals.

The annual production of simple antimony ore throughout the world amounts to over 30,000 tons; 50% normally comes from China, and the rest from Mexico, Bolivia, Yugoslavia, Czechoslovakia, Algeria and Italy. Most lead-zinc deposits (see *Lead*) contain a little antimony, which is generally extracted as antimonial lead, and this provides much of the antimony used throughout the world.

In India, small deposits of antimony have been worked in Chitral.

Arsenic.—By far the greater proportion of arsenic is used in chemical industries for the manufacture of compounds required in agriculture—tree sprays, etc. Some is used in glass manufacture and in drugs.

The world's annual production of arsenic is about 60,000 tons, mainly from Sweden, Italy, France, the United States, Mexico, Belgium, Australia, Japan, Germany and the United Kingdom. Although some arsenic ore is mined as such, the production is chiefly in the form of a by-product oxide, white arsenic, from the smelting of copper and lead ores. India has no workable resources of arsenic.

Asbestos.—There are two main varieties of asbestos: chrysotile, a hydrated magnesium silicate, and tremolite, a calcium magnesium silicate; the former is the more valuable. The main uses are: in asbestos textiles, yarns, cordage and cloth, in paper, compressed sheets, blocks, and brake linings, in such cement products as shingles and corrugated sheets, in heat-resisting articles,

in pipe and boiler lagging, in jointing materials, in paints and roofing cements, and for filtering fruit juices and acids, and packing, etc.

The world's annual production of asbestos is between 500,000 and 600,000 tons, of which more than 50% is from Canada. Other important sources are: U.S.S.R., Southern Rhodesia, South Africa, Cyprus, the United States, Italy, Finland and Czechoslovakia. India has small resources of asbestos, mainly in Madras, Mysore and Saraikela, but production has always been of very minor importance.

Barium.—The important barium mineral is the sulphate, barite, but the carbonate, witherite, is also mined. The principal use of barite is in the manufacture of lithopone, the basis of many paints, and it is applied as filler in the manufacture of motor tyres and other rubber goods, in paper, cloth and linoleum; it is also required in certain types of glass, enamels and glazes. Other uses are as a furnace lining, as a source of barium chemicals, and for weighting mud-fluid in rotary drilling on the oilfields.

The world's annual absorption of barium minerals is between 700,000 and 900,000 tons, of which Germany supplies about 50% and the United States about 30%. Other important sources are the United Kingdom, Italy, Greece, France and U.S.S.R. In India, deposits of barite in Madras, Rajputana (Alwar), United Provinces and Bihar have been mined in a small way. India's resources of this mineral are probably adequate to take care of domestic requirements.

Bauxite.—Bauxite is a hydrated oxide of aluminium. Besides being the principal ore for the extraction of aluminium it is used also for the purification of kerosene, for the manufacture of alumina cement, refractories, and abrasives, and for chemicals required in dyeing, tanning, printing, and other industries.

The world's consumption of aluminium has expanded enormously in recent years, and, before the war, was approximately 400,000 to 500,000 tons yearly, whilst the world's annual production of bauxite was nearly 4 million tons. About one-third of this bauxite tonnage was mined in France; other important sources were Hungary, the United States, Italy, Yugoslavia, British Guiana,

Dutch Guiana and U.S.S.R. Bauxite is mined also in other countries, such as Germany, Greece, Rumania, India, Australia, Gold Coast and other parts of Africa. The end of the war will probably witness a great change in the centres of aluminium production and a vast expansion in consumption. In India, deposits of bauxite are widely distributed but occur mainly in Bihar, the Western Ghats and United Provinces.

Cryolite, a sodium aluminium fluoride, from Greenland—small deposits are also known in Colorado and in the Urals—was formerly an essential constituent in the manufacture of aluminium, but nowadays artificial cryolite can be made from fluorite.

Bentonite.—The general term 'bentonite' has been applied to certain clays which consist mainly of the mineral montmorillonite, a hydrated magnesium alumina silicate. Until recently the term was restricted to clays which swell considerably on absorbing large amounts of water, but it now also embraces clays, similar to the fullers earth type, which do not noticeably absorb water and do not swell on wetting; there are all gradations between the two types. Bentonites are used in foundry sands, in soap-making, in ceramics, for thickening mud in oil well drilling, for filtering and decolourising oils, and for civil engineering purposes where a colloidal solution is required as a seal.

The United States is the largest producer of bentonite, but deposits in several other countries are also worked. In India, bentonite is available in Kashmir and Jodhpur.

Beryllium.—The metal beryllium is used in special alloys; the most important of these are copper-beryllium alloys which are used in the manufacture of castings, non-sparking tools, and a new type of diamond drill bit. The metal is obtained from the mineral beryl, a silicate of aluminium and beryllium. A small amount of beryl is also used in ceramics.

The world's annual production of beryl is only a few hundred tons, and in the past most of this has come from Rajputana in India, although in recent years the chief sources have been the United States and South America.

Bismuth.—The most important use of the metal bismuth is in medical chemicals; it is also a constituent of certain low-melting point and non-shrinking alloys.

Most of the bismuth consumed throughout the world is derived as a by-product of the smelting of ores of other metals in the United States, United Kingdom, Germany, France, Sweden and U.S.S.R. The amount of ore which is mined solely for its bismuth content is only about 400 to 600 tons per year, in terms of metal content; this comes mainly from Peru, Mexico, Bolivia, Rumania, China, Japan, Germany, Spain and Canada. In India there are no bismuth deposits which could be economically mined.

Borates.—Compounds of boron are widely used in chemical industries and as a flux in metallurgy. Large amounts are used in the manufacture of enamels, glass, soap, soap powders, medical products, baking powders, and food preservatives, and in the paper, textile and tanning industries. Boron has recently been introduced into certain metals to impart particular properties.

Of the world's annual production of crude borates, 200,000 to 300,000 tons, about 90% is from the United States. A little is obtained also in Argentine, Turkey, Italy, U.S.S.R. and Chile. India imports a few hundred tons annually from Tibet.

Bromine.—The liquid bromine is mainly required for the manufacture of tetraethyl lead which is added as an anti-knock compound to petrol. It also has important applications in chemical industries for the manufacture of a large number of compounds, such as those used in dyes, photography and pharmacy.

The world's total annual production of bromine is of the order of 30 million pounds. The chief sources are the United States, Germany, France and Palestine, but a little is also obtained in Italy, Japan and U.S.S.R.

Building stones.—Vast tonnages of building stones of all types are quarried throughout the world. Almost every country has its own adequate resources, but full statistics of annual production are not available.

Cadmium.—The metal cadmium is used in certain alloys, more particularly with copper for transmission wires. A cadmium-

cerium alloy is used for cigarette lighters. Some bearing-metals are of a lead-cadmium alloy, and some type-metal alloys contain cadmium. The metal is used also in electroplating and in accumulator cells. Other applications are in paints, glazes, photography and medicines.

Cadmium is obtained as a by-product from the treatment of lead-zinc ores. The average world production is about 4,000 to 5,000 tons per annum; about 40 % of this is from the United States, and most of the remainder is produced in Mexico, Germany, Canada, Poland, Australia, Norway, Belgium, the United Kingdom and Southwest Africa. India has no developed resources of cadmium. It is not known whether any is contained in the lead-zinc ores of the old abandoned mines of Rajputana.

Chromite.—The metal chromium is obtained in the form of an alloy, ferrochrome, by smelting chromite, an iron chromium oxide. Ferrochrome is used for the manufacture of special chrome-steels, and chromium itself is used for chrome plating. The mineral, chromite, is manufactured into refractory bricks for furnace linings. Oxides of chromium and alkali chromates are employed as pigments, and in dyeing, calico printing, and in tanning.

The world's normal annual requirements of chromite are approximately one million tons, the principal producing countries being U.S.S.R., Turkey, Southern Rhodesia, South Africa, Cuba, Yugoslavia, Greece, India, New Caledonia, Japan and the Philippines. Low grade deposits are known in other countries such as Borneo and Celebes. India's best deposits are in Baluchistan, but supplies are obtained also from Singhbhum (Bihar) and Mysore. Small deposits are known in Saraikela (Eastern States) and Ratnagiri (Bombay).

Clays.—Clays consist mainly of hydrated alumina silicates, with variable impurities. The more important uses of clays are in the manufacture of building bricks, cement, firebricks and other refractory articles, pottery and other ceramic ware, and as a filler in paper and textiles. In India clay is also used for medicinal purposes, for colour-washing, and for the manufacture of soap, etc.

Most countries have ample resources of clays for building purposes, and even for the manufacture of firebricks, but the better quality white clays, known as 'china clays', are not so common. Between 3 and 3·5 million tons of clays suitable for whiteware are required annually, the chief sources being the United Kingdom, the United States, Germany, China, Japan, Czechoslovakia, France, U.S.S.R. and Italy. India has no large deposits of china clay comparable to those in Cornwall, but there are many small deposits scattered throughout the Peninsula. The quality is very variable and, apart from a few deposits, is not up to the standard of European countries.

Coal.—In addition to its direct use as fuel for power purposes, a vast amount of coal is converted into coke for metallurgical and other purposes; much coke is also obtained as a by-product of gas production. The by-products from coal distillation provide the basis of several great chemical industries.

The world's normal annual production of coal in recent years has been of the order of 1,500 million tons. About one quarter of this is mined in the United States, the next largest producers being Germany and the United Kingdom. Other important producing countries are U.S.S.R., France, Japan (including Korea and Manchukuo), Poland, Belgium, Czechoslovakia, India, China, Australia, Canada, Netherlands and South Africa. India's coal mining is centred mainly in Bihar and Western Bengal. There are other important deposits, however, in the Central Provinces, Central India, Hyderabad, Eastern States and Assam.

Cobalt.—The metal cobalt is used in special steels of high magnetic permeability, in cutting steels, in cobalt-tungsten carbide and in electroplating. Cobalt salts find an application in paints and varnishes, and the oxide is used in ceramics.

The annual production of cobalt is about 3,000 tons. At one time the metal was obtained mainly from the cobalt ores of Canada, but today it is extracted as a by-product from the treatment of the copper ores of Northern Rhodesia and Belgian Congo. Some cobalt is obtained also from ores in French Morocco, Canada and

Burma. Cobalt minerals have been recorded from Rajputana and Nepal.

Columbite and tantalite.—Niobium oxide and tantalum oxide with iron and manganese form a continuous mixed series of which one end member is columbite and the other is tantalite. Both columbium and tantalum are used in metallurgy, and tantalum carbide is particularly valuable for the manufacture of cutting tools.

The bulk of the world's supply of columbite is from Nigeria, whilst tantalite comes mainly from Western Australia; Belgian Congo is an important source of columbite-tantalite. Small amounts of these minerals are found also in Uganda, the United States, Southern Rhodesia, Southwest Africa, South Africa, India and U.S.S.R. The Indian occurrences have been in Madura, Nellore, Salem, and Trichinopoly districts of Madras, in Mysore State, in the Bihar mica belt, and in Kashmir State.

Copper.—In addition to its necessity in the electrical industry the present day uses of copper are manifold in engineering appliances, either as copper or in brass, bronze and other alloys. Copper salts, particularly copper sulphate, are also widely used.

The total annual production of copper throughout the world in recent years has been between 1,400,000 and 2,000,000 tons. The United States provides about one-third of the total, the other principal countries being Chile (the largest individual ore-body in the world occurs at Chuquicamata), Canada, Northern Rhodesia, Belgian Congo and Russia, each with a production of over 100,000 tons annually. Other useful sources are: Japan, Mexico, Peru, Yugoslavia, Germany, Spain, Cyprus, Norway and Australia. Small quantities are produced in Cuba, Finland, South Africa, Southwest Africa, Sweden, India and Newfoundland.

In India, copper is mined and smelted in Singhbhum, Bihar. Small deposits have been recorded in Assam, Bengal, various parts of Bihar, Central Indian States, Central Provinces, Garhwal and Almora, Kashmir and Jammu, Madras, Mysore, Rajputana and Sikkim, but the majority of these are not of economic importance.

Diatomaceous earth.—This material consists mainly of the siliceous skeletons of minute marine and freshwater organisms. Diatomaceous earth is porous and is therefore an absorbent—it was utilised for this purpose in the explosives industry at one time. It is used for filtering sugar solutions, beers, wines and spirits, fruit juices and oils, and as a filler in paints, varnishes, paper and roofing material. It may be used in cement and mortars, and it is also a heat insulator.

Between 200,000 and 250,000 tons of diatomaceous earth are marketed annually, one-third of this quantity coming from the United States and Denmark. Deposits occur also in Japan, Algeria, France, Ireland, Germany, Australia, Italy, Spain, Portugal, U.S.S.R. and several other countries. There are no known workable deposits in India.

Feldspar.—The two commonest feldspars are orthoclase, a potassium alumina silicate, and plagioclase, a sodium calcium alumina silicate. Of these orthoclase is the more important in the ceramic and glass industries, although some soda plagioclase is also used. A certain amount of feldspar is marketed as an abrasive.

Between 500,000 and 550,000 tons of feldspar are mined annually in various countries. About half of this production is from the United States, the remainder being chiefly from Manchuria, the United Kingdom, Sweden, Czechoslovakia, Norway, Canada, Italy and Germany.

A few thousand tons of feldspar are produced annually in India, particularly in Rajputana and Mysore. Deposits of feldspar occur in several provinces on the Peninsula, and supplies will be adequate when the domestic demand warrants further development.

A material of similar value in the glass and ceramic industries is a rock which is high in soda and known as nepheline syenite. This is mined chiefly in Canada and U.S.S.R.; occurrences are known in Rajputana.

Fluorite (fluorspar).—The mineral fluorite, a calcium fluoride, is required in metallurgy as a flux, particularly in basic steel smelting where 5–8 lbs of fluorite are required on an average for smelting each ton of basic steel. Other uses are in the manufacture of glass

and enamel, and of artificial cryolite (a sodium aluminium fluoride) which is necessary in the production of aluminium. Fluorite is the source of fluorine and hydrofluoric acid required for chemical purposes. The mineral is used also in the manufacture of carbon electrodes, calcium carbide and cyanamid, and for the extraction of potash from felspar and cement flue dust; it is applied also as a pigment and as a binder for abrasives.

The total amount of fluorite produced annually throughout the world is of the order of 400,000 tons. Most of this is mined in the United States and Germany, but important amounts are produced in U.S.S.R., the United Kingdom and France. Some is obtained also in Italy, Korea, Spain, China, South Africa and Australia. Deposits are known in several other countries. In India, deposits in Khairagarh and Nandgaon States may be utilised in the near future.

Fullers earth.—The term *fullers earth* is applied to non-plastic clays which do not disintegrate in water, and which have the power of absorbing colouring matter from oil. Some non-swelling bentonites, after activation with acid, have similar properties as decolourisers.

Details of the annual production of fullers earth throughout the world are not known. The amount is probably of the order of a half to one million tons. It is obtained in many countries, the largest tonnage probably being from the United States. India's production of fullers earth amounts to only a few thousand tons annually, mainly from Sind, Bikaner, Jodhpur, and Khairpur, with a little also from Jubbulpore, Jaisalmer, Mysore and Jaipur.

Gold.—The total amount of gold which has been produced in the world appears to be divided between the national banks and ornaments. A little is used in the manufacture of gold leaf for gilding and of industrial and scientific appliances, and a very small amount finds its way into chemicals.

The amount of gold produced throughout the world in recent years has been of the order of 30–35 million ounces annually. About one-third of this is from the Rand in South Africa, and nearly half from U.S.S.R., Canada, United States and Australia

together. The remainder is distributed over a large number of producing countries, the principal, in order of importance, being: Korea, Southern Rhodesia, Mexico, Japan, Philippines, Gold Coast, Colombia, Belgian Congo, India, Chile, New Guinea, Sweden, Peru and New Zealand.

India's annual production is 300,000–400,000 ounces, and is mainly from the Kolar goldfields, but small amounts are obtained from Bihar, Hyderabad, and scattered parts of India.

Graphite.—The mineral graphite is one of the two natural forms of carbon—diamond is the other. Graphite occurs both in the amorphous form and as crystalline flakes. It is required mainly for the manufacture of crucibles, as a facing to foundry moulds, in paints, in pencils, and in lubricants. It is used also in electrodes, dynamo brushes and dry batteries.

The amount of graphite produced each year in various countries is between 120,000 and 150,000 tons, and this is obtained mainly in Korea, Ceylon, Austria, Germany, Czechoslovakia, Madagascar, the United States and U.S.S.R.

In India small scattered deposits of graphite have been worked in the Eastern Ghats, Central Provinces, Travancore, Ajmere-Merwara and Kolar. Carborundum and other refractory materials have restricted the demand for graphite.

Gypsum.—The hydrated calcium sulphate, gypsum, is used in special cements, as a flux, in paint, paper, etc. and as a fertiliser. On calcining it is converted to plaster of paris. Gypsum is used also for the manufacture of calcium sulphate and of sulphuric acid—for the latter purpose the related calcium sulphate, anhydrite, is also suitable.

The world's annual production of gypsum is about 10 million tons. Deposits are found in many countries, the principal producing centres being the United States, Germany, France, the United Kingdom, Canada, Italy, Spain, U.S.S.R. and Egypt. India's production is gradually increasing; it is obtained chiefly in the Punjab, Trichinopoly, Jodhpur and Bikaner, but there is also a small yield in Sind, Jaisalmer, Garhwal and Kashmir.

Helium.—The only country in which the natural gas, helium, is obtained is the United States. Besides its value as a non-inflammable gas for balloons used for many purposes, oxygen-helium mixtures have been of assistance in deep-sea diving. Other applications are in the treatment of asthma and kindred respiratory diseases, and in the administration of anaesthetics.

Iodine.—Besides its value for medicinal purposes, iodine is useful in dye manufacture, tanning, photography, and in various laboratory reagents. About 2·5 million lbs are absorbed annually throughout the world, the greater part of which is obtained from the nitrate deposits of Chile. There is also some production in Java, Italy, the United States, U.S.S.R., Poland and Mexico.

Iron.—The world's annual pig-iron requirements in recent years have been of the order of 90–100 million tons; the annual steel production has been 100–130 million tons, a considerable proportion of which has been from scrap metal. The iron ore resources of the world are incalculable, some of the largest deposits occurring in countries where production is as yet small, as in India and Brazil. The principal centres of iron and steel smelting are: the United States, Germany, U.S.S.R., the United Kingdom, France, Japan, Belgium and Luxemburg, India, Australia, Czechoslovakia, Canada, Italy and Sweden.

India's output of iron and steel is steadily increasing, and is based on the vast deposits of Singhbhum and adjacent Eastern States; there is also a small output in Mysore. Deposits of iron ore occur in other parts of India; the development of a smelting industry in the Central Provinces is conceivable, based on the iron ores and limestones of Drug and adjacent States, and the coal of Korea and Rewah. India's resources of high grade iron ore probably exceed those of any other country.

Kyanite, sillimanite and andalusite.—These three minerals are aluminium silicates having the same composition. With them may be included dumortierite which also contains a little boron. These minerals are all used in the manufacture of high quality refractory bricks, especially for furnaces required for glass melting.

They are also made into high quality porcelains, such as are used in spark plugs.

Deposits of both kyanite and sillimanite are available in India, but only the kyanite is accessible—in Kharsawan State the great Lapsa Buru deposit, the largest of its kind in the world, has provided the principal production which is steadily expanding. Dumortierite is also present in these deposits.

Although andalusite, kyanite and dumortierite are mined in the United States, the deposits are not comparable in quality with the Indian.

Lead.—Apart from the use of lead as a metal and in alloys, it enters into many paints in the form of oxides, and red lead is used in storage batteries.

The world's annual production of lead is between 1,200,000 and 1,600,000 tons. The principal sources are the United States, Australia, Mexico and Canada, but useful amounts also come from Burma, Yugoslavia, Germany, U.S.S.R., Peru, Spain, the United Kingdom, Italy and Newfoundland.

There has been no important production of lead in India. Small deposits have been recorded in various places, mainly in Bihar, and although small parcels of ore have been smelted at times there has been no deposit developed which would sustain a payable industry. The lead-zinc deposits at Zawar, in Mewar, Rajputana, may eventually provide an important production.

Limestone.—Calcium carbonate, in the form of limestone, enters largely into industry for the manufacture of lime and cement, as a flux in metallurgy, as a building stone, as a filler and abrasive, and in agriculture. Pure limestone is required for glass melting, for bleaching powder, and for calcium carbide.

Most countries have adequate supplies of limestone. Details of production throughout the world are not available, but the annual total must be of the order of several hundred million tons. In India, deposits of limestone are widespread, quarries have been opened in almost every province, and the production of cement is steadily increasing.

Lithium.—The metal lithium is contained in several minerals of which three are of commercial value: spodumene, a lithium alumina silicate, lepidolite, a lithia mica, and amblygonite, a lithium alumina fluor-phosphate. Lithia salts and the metal lithium are manufactured from spodumene and amblygonite. Lithium tends to increase the hardness, toughness, and tensile strength of some metals, and acts as a purifier; it is normally introduced into the melt as a calcium-lithium alloy. Lithium chloride is used in air conditioning and as a flux in welding; other lithium salts have a variety of uses. Lepidolite is added to certain glasses.

The important lithia producing countries are the United States, Southwest Africa and Argentine, but some is obtained also in Canada, Sweden, Germany, Czechoslovakia, France, Spain, Portugal and Western Australia. The annual production is of the order of a few thousand tons. In India, lepidolite is known to occur in Bastar.

Magnesite.—The magnesium carbonate, magnesite, is used principally for making refractory bricks for metallurgical furnaces. It may also be used for the extraction of the metal magnesium.

The world's normal annual requirements of magnesite are about 1,200,000 tons of which rather more than half is produced in U.S.S.R. and Austria. Other important sources of supply are the United States, Greece, Manchukuo, Yugoslavia, Czechoslovakia, Canada, Australia, India and Germany. The Indian production is from Madras and Mysore, but deposits in Idar State are also available.

Magnesium.—The metal magnesium and also magnesium alloys are used in aircraft, automobile, and textile industries, and for incendiary bombs. The principal alloy is with aluminium. The metal is generally obtained from magnesian liquor, a by-product of the manufacture of salt from brines, but magnesite may also be used. There has been an enormous expansion in the output of this metal since 1938.

Manganese.—About 95% of manganese ore production is used for metallurgical purposes, in the smelting of iron and steel, and in special alloys. A very high grade ore is used in the chemical,

ceramic, and glass industries, and in dry batteries. Manganese oxides are used in paints.

The world's requirements of manganese ore vary according to the iron and steel output. In recent years the annual production of ore has ranged between 3 and 6 million tons, most of which has come from U.S.S.R. and India, but Gold Coast and South Africa are also important sources. In addition, useful quantities of manganese ore are mined in Brazil, Egypt, Czechoslovakia, Cuba, Japan and the United States. Small amounts are produced in many other countries.

The bulk of India's production is from the Central Provinces, but important quantities are obtained in Bihar and adjacent Eastern States, Madras States and Western India States. Exports from India vary widely according to demands from overseas iron and steel industries, ranging between 300,000 and one million tons annually.

Mercury.—The metal mercury is used in amalgam, and in thermometers and barometers; a little is also required for mercury boilers and mercury vapour lamps. Mercury fulminate is one of the essential detonators for explosives. Mercury compounds are used as pigments and in medicines.

Between 8 and 10 million pounds of mercury are produced annually throughout the world. More than 75% of this total comes from Italy, Spain and the United States, each of which produces between 1 and 5 million pounds annually. Other important sources are U.S.S.R., Mexico and Czechoslovakia, whilst small amounts are obtained in Bolivia, China, Japan, Korea, Australia, New Zealand, Rumania, Austria, Germany, Turkey, Tunis and Algeria.

Mica.—The two micas of commercial value are muscovite, the potassium alumina silicate, and phlogopite, the potassium magnesium alumina silicate. Both are used in the electrical industry as insulators, but muscovite has a much wider use in condensers, radio tubes, furnace windows, etc. Thin films are cemented together to form micanite, perhaps the most important insulating material used in electricity. Finely ground mica is used

in the manufacture of patent roofing, wall paper, automobile tyres, moulded insulators, rubber goods, fancy paints and lubricants.

The world's normal annual requirements of sheet mica in recent years have been 8,000–14,000 tons, 70 to 80% of which comes from India. Other important producing countries are the United States, Brazil, Madagascar, Canada and Argentine; a large production in U.S.S.R. is absorbed entirely within that country. Small amounts are produced from Norway, Sweden, Italy, Rumania, Australia, Tanganyika, Rhodesia and Korea.

The demand for ground mica, derived from scrap, is steadily mounting and is between 20,000 and 30,000 tons per year. Most of this is produced in U.S.A., but much is now despatched from India and a considerable amount from South Africa and Canada.

India's mica mining is best developed in Hazaribagh district, Bihar; there is also a large industry in Nellore district, Madras, and increasing production in Rajputana. Deposits are known in other parts of India, but they cannot normally compete with the trade of the three principal localities.

A variety of mica known as vermiculite is mined in the United States and Tanganyika. It expands to a remarkable extent on heating, becoming a valuable sound and heat insulator. No vermiculite has been found as yet in India, but some of the weathered biotite associated with the mica deposits simulates vermiculite by expanding a little on heating—this is not true vermiculite, however.

Mineral pigments.—The natural mineral pigments include ochres, umbers, siennas, and ground rock such as slate and shale. Other pigments are prepared by the heat-treatment of ores, or by the chemical treatment of minerals and metals.

Vast quantities of natural pigments are produced annually in many countries but details of tonnages do not appear in statistics. Natural pigments occur in several parts of India, but the trade in them is not considerable.

Molybdenite.—The metal molybdenum forms one of the ferro-alloys, and is used particularly for high-speed tool steels. A little molybdenum is required also in chemical compounds and in ceramics.

Molybdenite, the ore from which the metal is obtained, is a sulphide of molybdenum. The world's annual production in recent years has been 20,000–24,000 tons, 66% of which comes from the Climax mine in Colorado and a useful production from Arizona and other States. Mexico also provides important amounts, and a little is mined in Norway, French Morocco, Korea, Australia, Turkey and Japan. Molybdenite is now being recovered also as a by-product from copper ores in Chile, Utah, New Mexico and Arizona. No deposits of molybdenite are known in India.

Monazite.—The world's requirements of monazite, from which thoria is extracted for use in the manufacture of gas mantles and as a catalyst in the Fischer-Tropsch synthetic benzine process, is not so great now as earlier this century. It is also the source of cerium, a constituent of the pyrophoric alloy used in pocket lighters and in tracer bullets. Most of the world's production is from India (Travancore)—3,000 to 4,000 tons annually—with some also from Brazil and Netherlands East Indies. Deposits are known in other countries.

Although monazite is obtained only as a by-product from the ilmenite sands of Travancore, occurrences of the mineral are known in the sands of other parts of the Peninsular coast.

Nickel.—The principal use of nickel is in special steels, such as stainless chrome-nickel steels, but considerable amounts are alloyed with other metals. Monel metal is a copper-nickel alloy which has an extensive range of uses.

Of the world's annual production of nickel, 90,000–120,000 tons, Canada supplies about 85%. New Caledonia provides the next largest yield but, had it not been for the war, production from Finland would have been very appreciable. Small amounts are obtained in U.S.S.R., Norway, Burma, Greece, Germany and Netherlands East Indies, and deposits are known also in Brazil, Italy, Japan, Southern Rhodesia and Yugoslavia. The only nickel known in India is a small percentage in the copper ore smelted by the Indian Copper Corporation and possibly in the copper ores of Rajputana. It has also been reported from Nepal.

Nitrates.—Natural nitrates are used mainly as fertilisers, and also in the manufacture of explosives and chemicals.

The production of natural nitrates has declined since 1918, consequent upon the introduction of synthetic nitrates obtained by fixation of atmospheric nitrogen. Most of the natural nitrates come from Chile, where the production is normally over one million tons annually. Negligible quantities are obtained in India, Egypt, Peru, China and Spain. India's production of nitrates, amounting to only a few thousand tons annually, comes from the surface soils of Bihar, Punjab and United Provinces.

Petroleum.—The world's annual production of petroleum is 200–280 million tons, of which about 60% is from the United States, with U.S.S.R. and Venezuela taking second and third place respectively. Important quantities are also obtained from Iran, Rumania, Netherlands East Indies, Mexico, Iraq, Colombia, Peru, Argentine, Trinidad, Burma and India. Germany and Japan have attempted to make up for their deficiency in natural petroleum by hydrogenation of coal. India's petroleum deposits are in Assam and Punjab.

Phosphates.—The dominant use of rock phosphate is for conversion into the fertiliser, superphosphate. A little is absorbed in the manufacture of elemental phosphorus and chemicals.

Between 8 and 12 million tons of rock phosphate are required annually throughout the world, the principal sources being the United States, U.S.S.R., Tunis and French Morocco. Nauru, Ocean Island, Algeria, Egypt and Christmas Island also provide considerable amounts. In the principal steel producing countries the high-phosphorus basic slag from steel smelting is used also as fertiliser.

In India, a small amount of phosphate is obtained from Madras and Singhbhum—the latter deposits are capable of more vigorous development should the demand arise.

Platinum metals.—The platinum group of metals includes platinum, palladium, iridium, osmium, rhodium and ruthenium. Besides the demands of the jewelry trade, platinum is required in chemical and electrical industries, and in dentistry. Palladium has similar uses to platinum. Iridium is alloyed as a hardener

with platinum, and is also used as a catalyst in chemistry. Osmium is mainly required for pen points. Rhodium-platinum is used in thermocouples (for high temperature measurement), and in spinnerets in rayon production. Ruthenium is used as a hardener in platinum.

The world's annual production of platinum is 250,000 to 300,000 ounces, of palladium about 100,000 ounces, and of the other metals a total of about 20,000 ounces. The greatest output of these metals is from the Acton refinery near London, where the precious metal concentrates from the nickel-copper ores of Sudbury, Canada, are treated. U.S.S.R. and South Africa are also large producers. Small amounts are obtained in Australia, Belgian Congo, Sierra Leone, Abyssinia, Colombia, Alaska, the United States, Japan, Papua, Netherlands East Indies, New Zealand and Panama. There are no known workable deposits in India.

Potash.—The principal use of potash is as a fertiliser, but large amounts are used in the glass and ceramic industries and in many chemical compounds.

The world's annual production of potash minerals, in terms of their K_2O content, is between 2 and 3 million tons. The greater part is mined in Germany but large deposits occur also in the United States, France, Spain, U.S.S.R. and Poland. Small deposits are available in several other countries. In India, potassium salts are collected from the surface soils in Bihar, United Provinces, Punjab and Madras, and a certain amount is obtained from the salt lakes in Sind.

Precious stones.—Apart from its value as a precious stone, diamond has many industrial applications which depend on its great hardness, but, for these purposes, inferior quality diamonds are used. Set in the drill-head, it is used to bore holes in rock to great depths. It is used as a cutting medium in diamond impregnated wheels and tools, and as an abrasive and polishing powder. Textile and metallic threads are drawn through diamond dies and guides.

The world's total annual output of diamonds in recent years has ranged between 8 and 11 million metric carats, more than half

being from Belgian Congo. Other large producers are South Africa, Gold Coast, Sierra Leone and Angola; Brazil and Southwest Africa are also important. In actual value, South African diamonds represent half the annual production. India has a small production, mainly from Central Indian States, but stones are found occasionally in the Cuddapah, Anantapur and other districts of Madras, and also in Chanda and Sambalpur districts.

The many other varieties of precious and semi-precious stones have not the same extensive use and sale as diamonds.

Rubies are obtained mainly from Burma, Siam, Ceylon and Kashmir, but are also found occasionally in Queensland, Afghanistan, China, Russia and the United States.

Sapphires are found in Burma, Ceylon and Kashmir.

Emeralds and aquamarines come from Colombia, Brazil, Russia, Australia, the United States, Ceylon and Madagascar.

Gem topaz is obtained mainly from Brazil, but crystals are also obtained from Burma, Ceylon, U.S.S.R. and Scotland.

Gem zircons are found in Ceylon, Siam, Indochina, Burma and Australia.

Jade comes from China, Burma, Tibet, Turkistan, Siberia, New Zealand, Alaska, Mexico and South America.

Rock crystal, or quartz, is obtained from Japan, Brazil, Madagascar, Switzerland and the United States. Small crystals are found in several parts of India. Amethyst is obtained from Brazil, Ceylon, Madagascar, Iran, Mexico, United States and in India in Santal Parganas, the Central Provinces and Kathiawar. Rose quartz is also available in Hazaribagh and Vizagapatam.

Opal is found mainly in Australia, Czechoslovakia, Mexico and the United States.

Turquoise is mined in Iran and Egypt.

Lapis-lazuli occurs in Afghanistan, Siberia, Chile and California.

There are a number of other precious and semi-precious stones obtained in various parts of the world.

In India mining for precious stones, except in Central India, is quite unimportant.

Radium and uranium.—Radium is obtained from uranium ores. Almost the sole use for radium is in medical therapy; the chief use for uranium is as an oxide which imparts a golden glaze on pottery and a yellow and orange colour to glass. About 50% of the world's radium and most of the uranium salts come from Canada. Czechoslovakia, Portugal, Belgian Congo, U.S.A. and U.S.S.R. have also yielded important amounts.

Salt.—Apart from its necessity in food, common salt is one of the fundamental raw materials of the chemical industry, as from it many sodium compounds are derived, and these are used in textile, rayon and cellulose, paper, soap, rubber, petroleum and many other industries. Salt is also the source of chlorine and hydrochloric acid.

The world's annual salt requirements are of the order of 30 to 40 million tons. The greater part is obtained by the evaporation of sea and lake brines in many countries; about 6 to 8 million tons is rock salt. The majority of the larger countries have more or less adequate supplies. In India, salt is obtained by the evaporation of sea brines at many points along the coast, by the evaporation of inland salt lake and sub-surface brines, and from rock-salt mines in the Punjab.

Sand and gravel.—Immense quantities of sand and gravel are excavated annually for building and other constructional purposes in almost every country. Perhaps the greater part is required for concrete. Special grades of sands are used in various industries, *e.g.* moulding sands in foundries, silica in refractories and in steel smelting, glass sands, filter sands, and abrasive sands. India has adequate resources for building purposes; high grade silica, from quartzite, is also available for the manufacture of refractory bricks, but further deposits of high quality silica, suitable as glass sands, are still being sought.

Selenium.—The principal use of the metal selenium is as a decolouriser in glass and to produce ruby glass; minor uses are in photoelectric cells, rubber goods, and maroon pigments and to increase the machinability of steel and copper alloys. The annual production is 300–500 tons, nearly all of which comes from the United States and Canada.

Silica.—See *Sand*.

Silver.—Apart from its use in coinage and silverware, silver has an extensive application in photography and recently in certain industrial alloys.

The world's annual production of silver is of the order of 250 million ounces, more than half of which is from ores which are worked primarily for lead, zinc and copper, and only about one-third is from ores in which silver is the principal valuable constituent. About three-quarters of the world's supply is from the American continent, about 50% of the total supply coming from Mexico and South American countries. The principal producers are Mexico, United States, Canada, Peru and Australia, followed by Japan, Bolivia, U.S.S.R., Burma, Germany, Belgian Congo, Honduras, Yugoslavia, Spain, Newfoundland, Chile, Korea, South Africa, Sweden, Czechoslovakia and Netherlands East Indies. In India, rather over 20,000 ounces are obtained annually from treatment of the gold on the Kolar goldfields, Mysore.

Slate.—Not only is slate required for roofing purposes but also for flooring, billiard tables, school slates, etc.; in the powdered condition it is used in abrasive soaps and polishers and as a filler in paints, rubber and linoleum.

Several million tons are quarried annually in many parts of the world. In India the principal sources are in the Kangra Valley, Punjab, and in Bihar.

Sodium.—Soda ash, Na_2CO_3, and salt cake, Na_2SO_4, are two important industrial compounds, required especially in the manufacture of glass, soap, dyes, paper pulp, textiles and heavy chemicals. They do not occur particularly abundantly in nature, and are largely manufactured from other sodium compounds, generally from sodium chloride (see *Salt*). In India, soda is extracted from alkaline (*Reh*) soils in Bihar, United Provinces, Mysore and Bombay, and also from Lonar Lake in Berar and from the alkaline lakes of Khairpur and Sind. The manufacture of these two sodium compounds from salt brine is gradually increasing in India.

Strontium.—The principal uses of strontium are in flares and fireworks, but strontium minerals are used also in refining beet sugar, in paints as fillers, and in metallurgy and medicine.

The world's production of strontium minerals is of the order of 10,000 tons annually. Most of this, as celestite (strontium sulphate), is from the United Kingdom; strontianite (strontium carbonate) is obtained in Germany. Deposits of celestite are known to occur in the surface soil in parts of Madras.

Sulphur.—Sulphuric acid enters into a large number of chemical and other industries. Elemental sulphur is required in several heavy chemical industries, in pulp and paper industries, in fertilisers, insecticides, explosives, dyes, rubber, food products, oils and varnishes, etc.

The world's total annual production of sulphur is difficult to estimate, but it is of the order of 5-6 million tons. About 50% is from pyrites (iron sulphide), much is from deposits of natural sulphur, and some is collected either in the form of acid or elemental sulphur as a by-product from furnace fumes in treating sulphide ores. Increasing amounts of sulphuric acid are now being obtained from the treatment of gypsum. The more important producing countries are the United States, Italy, Norway, Japan, Cyprus, Germany, Portugal, France, U.S.S.R., the United Kingdom, Canada, Australia and Sweden.

In India, natural sulphur is available on Koh-i-Sultan, and at Sanni, in Baluchistan. Deposits of pyrite are known in the Kaimur hills, Bihar, and in the Himalaya, near Simla. The roaster gases at the copper smelters, Maubhandar, in Bihar, could be used for sulphuric acid manufacture if the acid could be absorbed by a local industry. The gypsum deposits of the Punjab will undoubtedly be a source of sulphur in the future.

Talc (steatite, soapstone).—Steatite or soapstone has long been used in India as a potstone. The purer form of steatite, or talc, is a hydrated magnesium silicate, and is used as a polishing medium, as a filler in paint, paper, and textiles, and as a refractory in gas burners and small alkali smelting furnaces. Talc is also used in the manufacture of soap, wall plasters, lubricants, and for

foundry facings. Mixed with china clay for pottery, it increases the latter's resistance to thermal shock. Steatite slabs are used for switchboards, tanks, etc.

Between 400,000 and 500,000 tons of talc are produced yearly, and over one-third of this total is from the United States. Other important sources are Manchukuo, France, U.S.S.R., Italy, Norway, Austria, Canada, India and Germany. India's production, of the order of 20,000 tons annually, is mainly from Rajputana and Madras, but deposits are mined also in Central Provinces, Bihar, Central India, Eastern States, United Provinces and Mysore.

Tellurium.—This metal is used for toughening rubber and increasing the corrosion resistance of lead. Of the world's annual production of less than 100 tons, nearly all comes from Canada and the United States.

Tin.—The manufacture of tinplate absorbs large amounts of tin, and much is also required in several important tin alloys such as bronze, babbitt metal, solder, typemetal and white metal. Tin is also used for collapsible tubes, foil, pipes and chemicals.

The world's annual requirements of tin are between 150,000 and 200,000 tons. The main producing countries are Federated Malay States, Netherlands East Indies and Bolivia, but useful amounts also come from Siam, China, Nigeria, Belgian Congo, Burma and Australia. No tin is produced in India, but a small deposit was worked some thirty years ago in Hazaribagh district, Bihar.

Titanium.—The oxide of the metal titanium is the basis of certain modern brush and spray lacquers, and, because of its covering power, perfect whiteness and almost complete inertness, it is a valuable filler and pigment. As a pigment, it is used also in plastics, linoleum, coated textiles, rubber, wall-paper, printing ink, glass, ceramic glazes and enamelware. Titanium is used in steel alloys; it prevents the formation of blow-holes, and provides a shock and abrasion-resisting alloy. Added to chrome-nickel steel the metal titanium reduces intergranular corrosion. It is used also in some brass, bronze, and other alloys for special purposes. Negative electrodes, made from titanium compounds, magnetite and chromic

oxide, have been used in arc lamps. The tetrachloride is used for smoke screens, and the bichloride and sulphate in the dye industry.

The world's requirements of titanium oxide are derived almost entirely from the iron titanium oxide mineral, ilmenite, of which 200,000 to 300,000 tons are produced annually. About 75% of this quantity is from Travancore in India. The only other serious producer is Norway, although deposits are known in other parts of the world.

Tungsten.—The most important uses of tungsten are in high-speed cutting steels, and in tungsten carbide which is also a valuable cutting agent. Filaments of the metal are used in electric lights and radio tubes. Several compounds of tungsten find a use in chemical and pigment industries.

The annual production of tungsten ore, wolfram, in terms of tungstic oxide content, is about 20,000 tons. Normally, about half of this comes from China, but Burma, the United States, Portugal, Bolivia, Korea, Malay States and Australia are important contributors.

In India, a deposit at Degana in Jodhpur has been worked intermittently. During the 1914–18 war a small vein was worked near Tatanagar station, Bihar. A small occurrence in Central Provinces is also known, and a deposit at Chhendapathar, Bankura district, Bengal, has been found recently.

Vanadium.—The principal use of the metal vanadium is as an alloy to toughen steel, copper, and aluminium. Minor uses are: as a catalyst in the manufacture of sulphuric acid, in the manufacture of aniline black used in indelible ink, as a photographic developer and sensitizer, in medicine, in making paint driers, as insecticide, fungicide and fertiliser, in the guilding of pottery, and in glass for filtering out ultraviolet rays.

The demand for vanadium is very capricious and in consequence the production of ore varies widely from year to year, the maximum being about 3,000 tons in terms of vanadium content. The production is mainly confined to Peru, United States, Southwest Africa and Northern Rhodesia. Vanadium is also obtained from converter slags at steel works in Germany, Italy and U.S.S.R.

In India, there are deposits of vanadium-bearing titaniferous iron ores in Singhbhum, Bihar, and in the adjacent part of Mayurbhanj State. Their vanadium content is very variable, ranging up to 4% and over, but their treatment is difficult. These deposits will be mined in the future also for their titanium content, particularly when the Travancore ilmenite deposits are exhausted.

Zinc.—Galvanising and brass absorb most of the zinc production. Sheet zinc is also manufactured for many purposes, and the metal is used in die casting, in batteries, and for the manufacture of zinc oxide and other zinc compounds.

The world's annual zinc output is 1,500,000 to 1,800,000 tons. Its production generally accompanies that of lead, and the principal zinc mining countries are the United States, Australia, Canada, Germany, Mexico, Italy, Poland, U.S.S.R., Newfoundland, Burma and Yugoslavia. Several other countries contribute small amounts.

In India, the lead-zinc deposits at Zawar in Mewar may eventually yield an important contribution of zinc.

Zircon.—This mineral is used for the preparation of metallic zirconium. It is also required in special porcelains and glasses, and as an opacifier in some enamels. Crucibles and certain high temperature cements are manufactured from the mineral.

Zircon is obtained in Brazil, India, Australia and the United States. In India it is recovered as an additional product during the concentration of the ilmenite beach sands of Travancore; these sands contain about 6% of zircon.

CHAPTER III

THE MODE OF OCCURRENCE OF MINERAL DEPOSITS IN NATURE

The rocks forming the crust of the Earth have originated in several different ways, and the same processes which have formed the rocks have been responsible also for the development of mineral deposits.

There are three principal groups into which rocks may be divided: sedimentary, igneous and metamorphic.

The surface of the land is exposed to the decomposing action of water and air, and the loosened particles may be removed by wind and running water. They eventually become deposited over the flood-plains of streams, or in lakes and estuaries, or in the sea off the coast, thus giving rise to sediments which may consist of beds of sand, silt, and clay. Plant remains and calcareous and other organisms, on dying, may also give rise to beds of coaly, calcareous, or siliceous matter. Salts in lakes or lagoons may become so concentrated by evaporation of the water that the salts are precipitated. In some places extensive land-surfaces may become covered by sand, as in desert areas, or by fine wind-blown dust. These sediments later become consolidated—if deposited below water they may become elevated to form land-surfaces; they may become tilted and folded, and buried deeply into the crust before denudation of overlying rocks by rain and wind exposes them at the surface. In this way arise the bedded or *sedimentary* rocks as we know them, comprising beds or strata of such rocks as sandstones, conglomerates, shales, coals and limestones—fig. 1.

The temperature of the Earth increases from the surface downwards. From time to time volumes of rock deep within the crust or below the crust become molten—the reason for this change from the solid to the liquid state at certain points need not be considered here, it is still a subject for debate amongst geologists.

These volumes of molten rock—*magmas* as they are called—rise into the overlying rocks, either by absorbing part of the latter, or by pushing the solid rocks apart, or by following some line of weakness such as a dislocation plane within the crust—fig. 2. Here, in this new position, the magma cools down and the resulting solid rocks are known as *igneous* rocks. Should the molten material break through to the surface it will form lava flows—*extrusive* rocks; but where the magma crystallises at depth, below a roof of solid rocks,

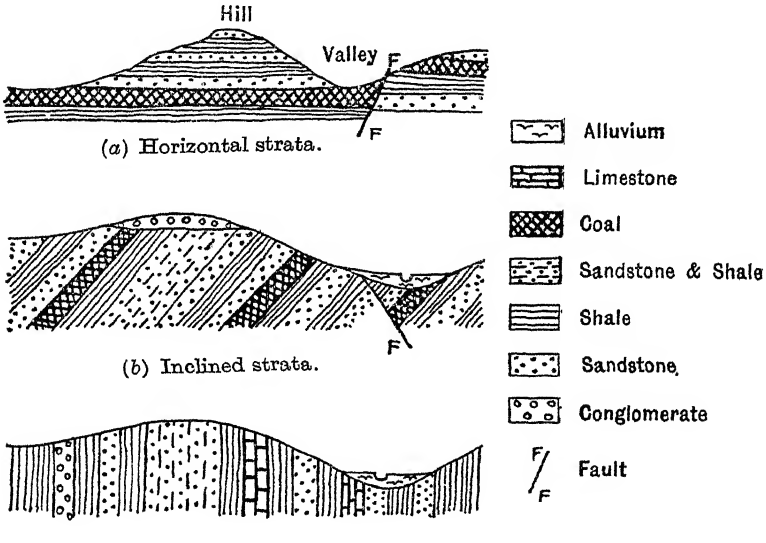
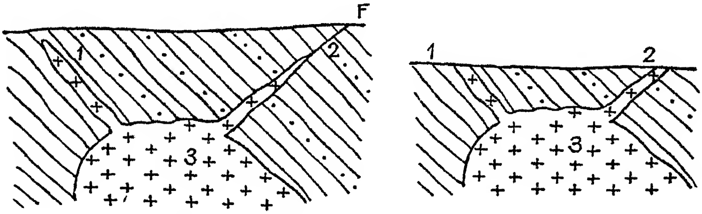


Fig. 1. Sections across sedimentary beds.

it is called a *plutonic* or *intrusive* rock. Rocks which contain a high percentage of silica are described as *acid* rocks, those with a relatively low percentage of silica as *basic* rocks. Whilst the magma is cooling the several constituents composing the melt combine to form various minerals which crystallise out, not simultaneously, but according to a definite sequence. The early minerals to form may sink, or accumulate at certain points, leaving the still molten material with a composition now different from the original, as

certain constituents—those forming the early minerals to crystallise—have been extracted. The remaining magma may move upwards, or the successive crystals continue to sink, so that several rock-types may arise each different in composition from the original



(a) Before denudation. (b) After denudation.

FIG. 2. Section across an igneous intrusion.
1. Intrusion, or sill, along bedding.
2. Intrusion, or dyke, along fault.
3. Parent intrusive mass.

melt. The final liquid, before complete crystallisation of the whole melt, may consist largely of water with other materials in solution, such as silica, copper, lead, sulphur, and highly volatile gases. Under the tremendous pressure of the associated gases these residual

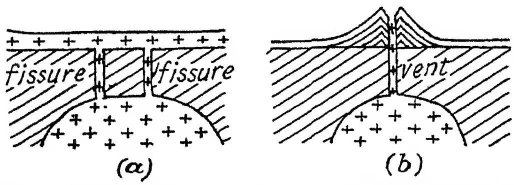


FIG. 3. Relation between intrusive magma and lava flow.
(a) Extrusion of lava through fissures.
(b) Eruption of lava through cylindrical neck of volcano.

liquids may be forced upwards along cracks and other planes of weakness in the crust, where they deposit their mineral content, thus giving rise to certain types of mineral deposits.

Both sedimentary and igneous rocks may be buried to great depths in the crust, and subjected to high temperatures and pressures. Or, around a magma which has intruded into sedi-

mentary rocks there may be a zone within which the temperature is raised considerably. Under these changed physical conditions, minerals which were originally stable now break down, react with each other and form new minerals. Under intense lateral pressure the rocks may be so squeezed that the minerals tend to arrange themselves in parallel directions and the rocks become cleaved (*e.g.* slates). In this way the original rocks may beccme completely recrystallised, to form *metamorphic* rocks. The process of

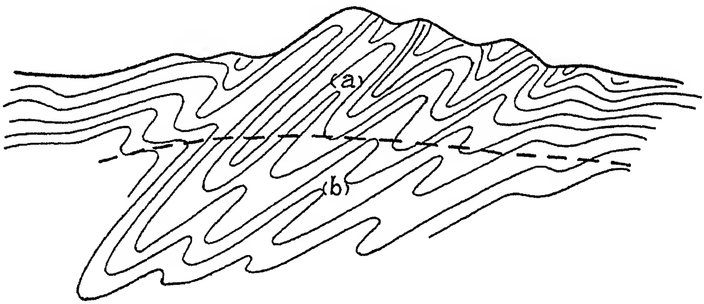
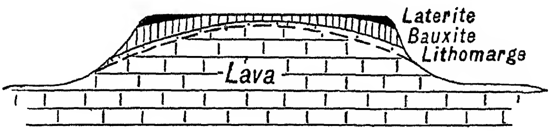


FIG. 4. Metamorphism in a region where the rocks are deeply folded.
(*a*) Zone of strong lateral pressure causing cleavage.
(*b*) Zone of increased temperature and pressure—recrystallisation.

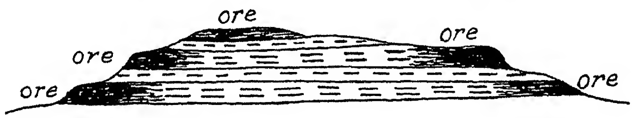
recrystallisation is governed by solutions which were either inherent in the original rock or given off from an adjacent magma. These solutions, permeating through the rocks, may remove certain constituents at one point and concentrate them at another, thus giving rise to *segregations* of certain minerals.

Any of these rocks—sedimentary, igneous, or metamorphic—may eventually be exposed at the surface. Here, by decomposition due mainly to the action of water, oxygen, carbon dioxide and organic life, the rocks give rise to soils. Under certain circumstances some constituents may be leached out so that the remaining rock is completely different in composition, or circulating ground-waters may exercise a selective action, concentrating certain constituents at particular points, perhaps thus giving rise to valuable mineral deposits—fig. 5.

Mineral deposits, then, like the rocks with which they are associated, have various modes of origin. Coal, limestone, and



(*a*) Formation of bauxite from lava on plateau top.



(*b*) Concentration of rich iron ore at outcrops of iron-bearing beds.

(*c*) Lateritic manganese ore over beds containing little manganese.

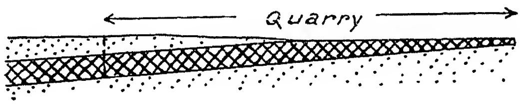
FIG. 5. Development of ore-bodies at the surface from underlying rocks.

certain forms of clay occur as well-defined beds within other sediments. Deposits such as copper, lead, gold, and mica have crystallised from solutions which have ascended from depths. Minerals like kyanite, sillimanite, garnet, and talc have been formed by processes of metamorphism generally at depth. Deposits such as bauxite, ochres, lithomarges and some iron and manganese ores have been formed by the selective action of circulating ground-waters.

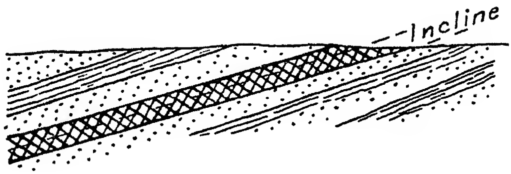
As may be readily appreciated, the mode of origin will determine to some extent the shape which a mineral deposit will assume, and the shape, or form, of a deposit will be an important factor governing the method by which it is to be mined.

Mineral deposits of sedimentary origin generally have a bedded or tabular form. The commonest deposits of this origin are coal, limestones, iron ore, clays, and building stones. In the case of coal

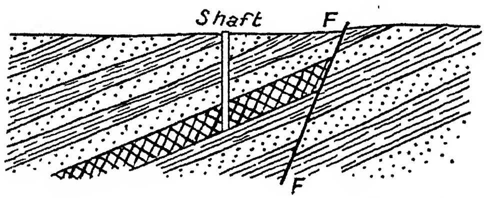
they are usually known as coal *seams*. The beds may be either horizontal, gently inclined (or *dipping* from the horizontal), steeply inclined, or vertical, and may be either widely exposed at the surface or buried beneath a considerable overburden of other material—factors of considerable importance in determining the cost of the method of mining which is to be adopted.



(*a*) Flat-dipping coal seam exposed at the surface —quarried.



(*b*) Dipping coal seam exposed at surface (or beneath thin alluvium)—worked by incline.

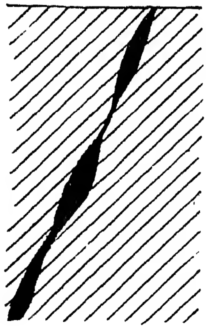


(*c*) Faulted coal seam not exposed at surface —worked by shaft.

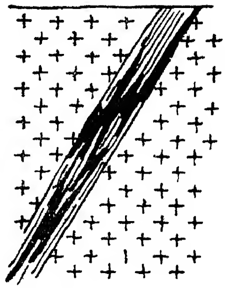
FIG. 6. Effect of overburden in working a coal seam.

The shapes assumed by those mineral deposits which have crystallised from solutions of deep-seated origin will depend to a considerable extent upon the form of the plane or zone of weakness within which the minerals were deposited. As the mineral solutions move upwards they may dissolve some constituents of the rocks

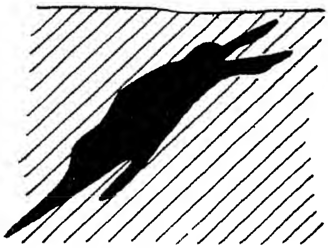
through which they pass, depositing others in the place of the removed material: this is known as *replacement*, perhaps the most



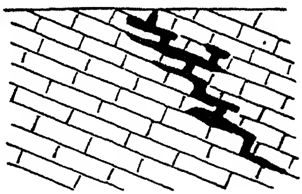
(*a*) Vein infilling fault openings.



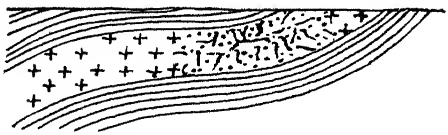
(*b*) Lode replacing sheared rock.



(*c*) Lenticular replacement mineral deposit.



(*d*) Irregular replacement deposit.



(*e*) Disseminated ore in granitic intrusion.

FIG. 7. Some forms of mineral deposits.

important process in the formation of most mineral deposits. Should a particular bed of rock be porous, the solutions may

permeate along it, and the resulting mineral deposit may then assume the tabular form of the original sediment, thus simulating a deposit of sedimentary origin. If the solutions find their way along a fault or fissure, part of which has an open space between the walls, the solutions may deposit minerals to fill the space thus forming a *vein* or *lode*. The ascending solutions may be injected under such intense pressure that the fissure walls may be forced apart, and the minerals may then be deposited in the space thus formed. It is not improbable that, as the minerals separate from the solutions, their very growth exerts an enormous pressure on the vein walls, pushing the latter apart. More generally, the rocks along a fault line may be closely sheared for a width varying in some cases to over 100 feet, and the solutions, ascending this highly porous sheared zone, may replace the sheared rocks thus forming a mineral deposit which may be identical in form with the vein or lode that has infilled an open fissure. Indeed there are few veins or lodes which do not show some evidence of replacement within them. This replacement may also take place irregularly, forming lenticular or irregular masses of mineral within the rocks. Or, again, the solutions may spread out along small fractures and joints, depositing the minerals rather sparsely over a considerable volume of rock —these are known as disseminated deposits. A particular form of such deposits, consisting of numerous ramifying veinlets, is known as a *stockwerk*. Most of the metals—antimony, chromite, copper, lead, nickel, gold, silver, and zinc—occur in veins, lodes or replacement masses, whilst feldspar, fluorite, and mica also generally occur in veins. Some of the greatest deposits in the world, those of copper in Chile, Arizona, and Northern Rhodesia, are of the disseminated type. If the minerals were deposited within veins or lodes, these will be of tabular form and may lie at all angles from horizontal to vertical; in length they may range from a few feet to thousands of yards, in width from a fraction of an inch to a hundred feet or more, and in depth they may extend to thousands of feet. The irregular massive replacement deposits and the disseminated deposits may also range enormously in dimensions and their longer axes may be inclined at all angles.

Any particular vein or lode may not be consistently rich or payable throughout its length or depth. Most lodes consist of an aggregate of various minerals: the useful mineral for which the lode is mined, and the valueless or *gangue* minerals. The valuable mineral may occur only in sections of the lode; these sections are known as *shoots*, the longer axes of which may be either vertical or inclined along the plane of the lode—fig. 8.

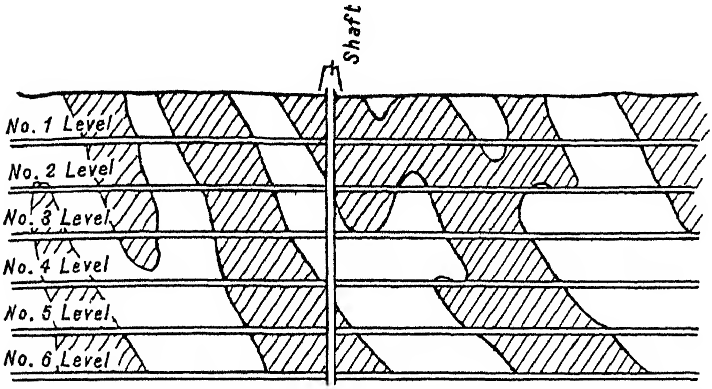


FIG. 8. Longitudinal section of lode showing payable mineral shoots.

Certain deposits, such as copper, tin, fluorite and muscovite, are noticeably associated with acid (granitic) rocks. Others, such as chromite, talc and magnesite, are associated with very basic intrusive rocks.

Within the metamorphic rocks, solutions have also been active in recrystallising the rock constituents, so that not unexpectedly the segregations of metamorphic minerals assume similar forms to those just described. Important representatives of this type are the minerals kyanite, sillimanite, andalusite and talc.

When denudation has exposed these various types of mineral deposits at the surface, and brought them within the influence of circulating ground-waters, the mineral constituents may be subjected to change. Some may be dissolved and leached away, others, after being taken into solution, may be concentrated in a particular

part of the lode. Thus, a deposit which may be rich at depth may be completely leached of its valuable constituents at, or close to, the surface; or a deposit which may be quite unpayable at depth may be so enriched in its valuable constituent by surface waters that it may be a very rich deposit indeed down to a shallow depth. Such *secondary* changes are generally confined to deposits of sulphide minerals (fig. 9) and gold, and do not affect minerals such as feldspar, fluorite, mica, barite, and chromite.

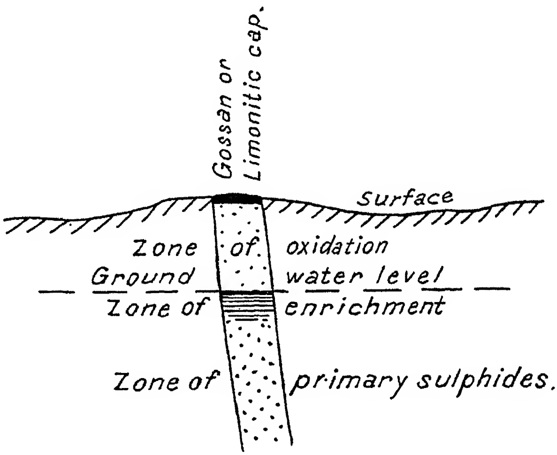


FIG. 9. Rearrangement of values in upper part of a copper deposit in a temperate climate.

Deposits of bauxite are formed by this type of surface concentration. Silica is removed in solution from the rock, and the increased alumina in the remaining rock is concentrated in the colloidal state at certain favourable points according to the drainage. In a similar way, manganese oxide, which may be in only very small amounts in the rock, may be concentrated into rich deposits at the surface. Beds of low grade iron ore may also, at the surface, be converted into quite rich ore (see fig. 5).

Minerals exposed at the surface are subject to the disintegrating action of wind and water, and may be carried down into the valleys along with the alluvial sediments. River waters exert a sorting

action, and valuable minerals like gold, diamonds, tin ore, tungsten ore and platinum metals, which are heavier than the associated sediments, may be concentrated along certain stretches of the river channels—commonly on the inner side of the bend of a stream where the current is checked. Even along the sea-shore the waves exert a similar sorting action, and minerals like ilmenite (titanium ore), monazite and zircon may be concentrated, as in Travancore.

It is of interest to summarise the general mode of occurrence of each of the principal minerals.

Abrasives.—Of the more valuable natural abrasives corundum occurs either in certain igneous rocks or as segregations within metamorphic rocks, in the vicinity of which it may be found in the surface soils. Garnets also occur in metamorphic rocks, mica-schists, which in some cases may be so rich in garnets that they can be payably mined, but more commonly the garnets are obtained from the stream sands which traverse the garnet-bearing rocks.

Antimony.—In nature antimony generally occurs as the sulphide stibnite, which is found in veins. Antimony minerals are also commonly associated with lead deposits.

Arsenic.—Most arsenic is obtained as a by-product from copper and iron sulphide deposits which are generally in the form of veins or large replacement masses. A few deposits of similar form are mined solely for their arsenic content.

Asbestos.—As a general rule chrysotile asbestos is associated with serpentine, an alteration product of very basic (ultrabasic) igneous rocks, and with magnesian limestones, whilst tremolite asbestos is associated more particularly with basic igneous rocks. In both cases the minerals have been developed by the action of solutions on the rocks. They form small veins or veinlets in the rocks, the fibres commonly arranged across the vein width, individual veinlets having been formed apparently by the fibres pushing the walls apart. The rock may be crowded with such veinlets.

Barium.—Both barite and witherite, the two barium minerals, occur as veins traversing different varieties of rocks, and as residual surface deposits formed by the weathering and denudation of rocks containing barite.

Bauxite.—Bauxite originates by the concentration, at or near the surface, of alumina from the underlying rocks. In past geological times there have been prolonged periods during which rocks have been exposed to weathering, permitting deposits of bauxite to form in places, and in some cases these have been covered over by later sediments. In India the majority of the bauxites are on the tops of high plateaux, and most commonly over traps or lavas.

Bentonite.—This variety of clay is generally thought to be an alteration product of basic igneous rocks, particularly of tuffs—fragmental material thrown out by volcanic action and deposited perhaps in the sea. It is normally in bedded form.

Beryllium.—The mineral beryl is a rare constituent of some mica veins, and is collected as a by-product, but most of the production in Rajputana is from pegmatites which are not normally worked for mica.

Bismuth.—Most of the world's bismuth is derived from bismuth minerals associated with tin, copper, and lead ores. A few veins of bismuth sulphide, bismuthinite, and native bismuth are mined in some countries.

Borates.—Most of the world's borate minerals occur as beds interstratified with other sediments. Some borate is obtained from the plateau lakes of Tibet.

Bromine.—This liquid is extracted from salt brines as a by-product, although at one plant in the United States it is obtained by the direct treatment of sea water.

Building stones.—Sedimentary building stones include sandstone, quartzite, flagstone, and limestone. Igneous rocks are also used, such as granite, basalt, syenite, porphyry, and anorthosite. Amongst the metamorphic rocks, slate, marble, and gneiss are the most commonly used.

Cadmium.—Certain vein deposits of lead-zinc contain minor amounts of cadmium, which is extracted as a by-product.

Chromite.—This oxide of chromium and iron occurs as veins and segregations generally within or closely associated with very basic intrusive rocks.

Clays.—Most brick clays are alluvial deposits. Fireclays are generally interbedded with other rocks. The best china clays or kaolins have been formed by the action of solutions, and perhaps gases, on the feldspathic constituents of granite.

Coal.—All coals, whether they be anthracites, coking coals, non-coking coals, or lignites, occur interbedded with other rocks. The beds may vary from an inch to hundreds of feet in thickness. As a general rule a seam less than 3 feet in thickness cannot be payably mined, but under exceptional conditions seams as thin as 2 feet can be profitably worked.

Cobalt.—Most of the world's cobalt is now derived as a by-product of copper deposits. Some veins of cobalt ore—complex sulphides—are still mined.

Columbite and tantalite.—The minerals of the columbite-tantalite series are found generally in small veins.

Copper.—Several copper minerals are mined, but the most important are the sulphides, chalcopyrite and chalcocite. The largest copper deposits in the world, in America, occur in a granitic rock, or porphyry, and consist of disseminated copper minerals which have been subjected to secondary enrichment, the enrichment in many cases extending down to hundreds and even thousands of feet from the surface. The Northern Rhodesian deposits are disseminations which have followed particular beds of sedimentary rocks. Important deposits occur also as veins and as irregular and lenticular replacement masses. The deposits in Singhbhum are in the form of replacement lodes.

Diatomaceous earth.—As it is of sedimentary origin, diatomaceous earth is found as beds interstratified with other sediments.

Feldspar.—Both potash- and soda-feldspars occur as constituents of certain veins, generally with some associated quartz.

Fluorite.—The commonest form of fluorite deposit is a vein, but irregular replacements are also known, particularly in limestone. Surface gravels shed from adjacent fluorite veins have been worked.

Fullers earth.—True fullers earths are in the form of bedded deposits, but certain Indian lithomarges have the property

of fullers earths and are due to the sub-surface alteration of rocks, such as traps.

Gold.—The greatest deposit of gold in the world is the 'banket' of the Rand, South Africa. This is an extensive sedimentary bed of conglomerate, the gold content of which is consistent over wide areas. It is still debated whether the gold was deposited at the same time as the conglomerate or was introduced by later permeating solutions. Most other gold deposits are in the form of veins, a few are replacement masses; the gangue mineral is generally quartz, but this is not invariable. Much gold is obtained as a by-product whilst smelting ores of other metals, particularly copper. Some gold, deposited in alluvium shed from gold-bearing rocks, is recovered by dredging or by other means.

Graphite.—Both flake and amorphous graphite occur as veins and segregations, although some deposits appear to be bedded in form; the deposits occur in metamorphic rocks.

Gypsum.—Beds of gypsum are interbedded with other rocks. The mineral is also found in surface soils.

Iodine.—Most of the world's iodine requirements are extracted as a by-product from bedded nitrates; some is obtained from salt brines, and a little from seaweed.

Iron.—Bedded deposits of iron ore provide most of the world's supply. In some cases these beds have been enriched by solutions at the surface or at favourable positions in depth. Veins and massive replacements or segregations of magnetite are also mined.

Kyanite, sillimanite, and andalusite.—These alumina silicates are of metamorphic origin, and generally occur as segregations, or in places as veins.

Lead.—There are many complex lead minerals, but the commonest is the sulphide, galena. All of the principal lead deposits of the world occur as lodes, some are of large dimensions, up to even 100 feet in width and thousands of feet in length.

Limestone.—All limestone deposits are in the form of beds, interstratified with other rocks.

Lithia.—The lithia-bearing minerals, spodumene, amblygonite, and lepidolite, occur as veins.

Magnesite.—Some magnesite deposits occur as replacement lenses in beds of dolomite, others have been formed by replacement of basic igneous intrusive rocks.

Manganese.—The principal deposits of manganese oxides occur as well-defined beds interstratified with other rocks. Some high grade small deposits, particularly in India, have originated by surface enrichment over rocks which may contain little or only a trace of manganese. A few deposits of manganese occur as veins.

Mercury.—In nature, mercury normally occurs as the brilliant red sulphide, cinnabar, which generally forms disseminated deposits.

Mica.—The variety of mica known as muscovite almost invariably occurs with quartz and feldspar as veins, both of fissure-filling and replacement origin; the latter may be varied, tongue- or pipe-shaped, in form. Phlogopite generally forms segregations and, in some cases, veins within, or close to, a certain type of rock described as pyroxenite, but which is apparently of metamorphic origin.

Mineral pigments.—The majority of ochres have been formed by the surface alteration of various rocks; they generally owe their colour to the presence of iron oxides. Some may be bedded. Umbers and siennas occur similarly.

Molybdenite.—Although molybdenite is commonly found in veins associated with other minerals, the two largest deposits, in the United States, are cylindrical-shaped ore-bodies the origin of which is still debated.

Monazite.—The world's supply of monazite is obtained mostly as a by-product during the extraction of ilmenite from beach sands.

Nickel.—The principal nickel minerals are complex sulphides which are found either as veins or as replacement masses of various forms.

Nitrates.—The Chilean natural sodium nitrates were deposited along an old shore line as irregular beds, and covered by a thin overburden. In India nitrates are obtained from the surface soils on the Gangetic Plains.

Petroleum.—Mineral oil and gas are tapped in permeable strata, in which they have accumulated in consequence of certain

favourable structural conditions. The hydrocarbons constituting the oil and gas are the alteration products of organic material.

Phosphates.—Most rock-phosphates represent vast accumulations of calcium phosphates deposited under marine conditions, and occur as beds. Others, such as on Nauru and Orean Islands, are found at the surface where the phosphatic material from bird refuse has replaced coral limestones. In Singhbhum, the mineral phosphate, apatite, occurs as veins, and in Russia certain basic igneous rocks rich in phosphates are mined.

Platinum.—A large part of the world's supply of platinum is obtained as a by-product from nickel-copper ores, some is derived from platinum ores, and the remainder is derived from alluvial river deposits.

Potash.—Most of the world's potash supply is obtained from beds interstratified with other rocks. Some is extracted from salt lakes, or from surface soils.

Precious stones.—The most valuable diamond deposit in the world, in South Africa, consists of a cylindrical-shaped or pipe-shaped igneous intrusive rock in which diamonds occur as a distinct mineral. Elsewhere, diamonds are found in certain beds of sandstone, and in surface debris shed from the latter.

The majority of other precious and semi-precious stones occur in alluvium, but some are found in rock formations.

Radium and uranium.—Uranium ores occur as veins.

Salt.—Large quantities of salt are mined underground from thick and extensive beds of the mineral. Most is obtained from brines from the sea, or from inland salt lakes and from sub-surface brines.

Sand and gravel.—Most sands and gravels for constructional purposes are excavated from surface alluvium, but special sands, of high purity, may be crushed from beds of sandstone and quartzite.

Selenium.—The selenium made available to commerce is a by-product from the smelting of copper ores.

Silver.—Although certain veins are worked solely for their silver content, the world's supply is mainly derived as a by-product from the treatment of ores of lead, copper, and gold.

Slate.—Quarries for the extraction of slate are generally located on extensive outcrops of beds of the rock.

Sodium.—Natural deposits of sodium carbonate and sodium sulphate occur as well-defined beds; some soda is obtained from inland lakes. Some of the soils of the Gangetic Plains are rich in soda, and it occurs also in the Lonar Lake, Berar, and in the soda lakes of Sind. Soda is mainly manufactured from common salt.

Strontium.—In Madras the strontium sulphate, celestite, occurs as small sparsely distributed veinlets in clay beds. In other countries it occurs as lenticles and veinlets in beds of marl, limestone, dolomite, and other sediments.

Sulphur.—Extensive deposits of natural sulphur occur inter-bedded with other rocks; some are related to volcanic activity, but the origin of certain deposits is still debatable. Much sulphur is obtained as a by-product in the treatment of metallic sulphide ores. Supplies have recently been obtained from gypsum.

Talc.—Although some talc is bedded in form most occurs as an alteration product of basic igneous or other magnesian rocks, particularly magnesian limestones, during metamorphism.

Tellurium.—The only source of tellurium is as a by-product from the treatment of other ores, such as those containing gold and silver tellurides.

Tin.—Cassiterite, the oxide of tin, occurs in veins and disseminations. Most of the world's supply is from river alluvium which has been shed from rocks containing veins and disseminations of the mineral.

Titanium.—The important source of titanium is the mineral ilmenite, which is concentrated from beach sands. Veins and segregations in basic igneous rocks are mined in some countries. A less important source is the oxide, rutile.

Tungsten.—Both wolfram (iron-manganese tungstate) and scheelite (calcium tungstate), the ores of tungsten, occur in veins. Alluvial deposits shed along river valleys from these veins are also worked. At Degana, Jodhpur State, the mineral occurs as small veins and stockwerks within a hill of granite and phyllite, and as eluvial deposits around the base of the hill.

Vanadium.—Some vanadium ores occur as veins, and others in interstratified beds; vanadium is also known to occur in segregations and veins of titaniferous iron ores, as in Singhbhum and Mayurbhanj.

Zinc.—The principal zinc mineral is the sulphide, sphalerite, generally found in association with lead.

Zircon.—Zircon deposits occur as river or beach sands, and in India the mineral is obtained as a by-product during the concentration of ilmenite sands.

CHAPTER IV

TESTING AND GRADING MINERALS

It is not intended in this chapter to detail the various methods by which minerals are identified and tested; such information would not be understood, perhaps, by the majority of laymen, and also it is generally inadvisable for the latter to rely upon such determinations as they themselves may make. However, in submitting a mineral for examination it is essential to have some idea of the properties, chemical or physical, which should be known before its commercial value can be considered.

Apart from one or two companies which have specialised in certain minerals, there are few institutions in India which have been available to the public for the testing of mineral raw materials; in the past almost the whole burden of this work has fallen on the Geological Survey of India to which many hundreds of samples are submitted annually. The Geological Survey laboratory is equipped for the analysis of minerals, and simple tests can be made to decide the suitability of minerals for certain purposes, but it is not equipped to carry out research on the treatment of minerals, such as methods of concentration or beneficiation or processing for a variety of industrial purposes. Certain companies have their own experimental laboratories, adapted to their special requirements, but a national experimental laboratory to which all could turn for advice would undoubtedly be of advantage to India's mineral industry.

In submitting material for examination, care should be taken that the sample is representative of the mineral deposit as a whole (see chapters V and VI), or of what can be readily sorted and despatched. Only too often carefully selected high grade specimens are submitted, which are not representative of the material available for economic exploitation—it has not infrequently been found that, after wasting time on careful tests, the specimen submitted represented almost all there was of the mineral!

Abrasives.—The most essential property of an abrasive is hardness, as it is on this that the cutting or abrading power of the material depends. With this must be combined toughness, for the effect of hardness will be annulled if the material breaks up readily under the shattering action of the process of abrading. The scale of hardness used is an extension of Moh's scale on which the harder minerals are listed as follows: feldspar—6, quartz—8, topaz and garnet—10, corundum and tungsten carbide—12, silicon carbide—13, boron carbide—14, diamond—15. There is still no compound harder than diamond.

Apart from their identification, such natural abrasives as corundum and garnet need little testing. They should be fresh and unaltered; the minimum grain size of garnets should be about the size of a pea. The more common natural abrasives are best tested for their particular purpose by actual submission to the users.

Antimony.—Samples require to be assayed for their antimony content, and the possible presence also of gold and silver may be tested. Examination under the microscope is helpful.

Arsenic.—Determination of the arsenic content of the samples is generally all that is required.

Asbestos.—It is necessary to determine first whether the sample is of the chrysotile or tremolite variety; the former is the more valuable. A simple field test is to teaze out the fibres then bend them rapidly over the thumbnail; chrysotile will remain unbroken, but tremolite is more brittle and will soon break. A very reliable test is to fluff the fibres between the fingers, mix with a 1% solution of iodine in glycerine, and examine under the microscope—chrysotile fibres are stained, other fibres remain unaffected. Chrysotile fibres rarely exceed more than 2-3 inches in length, but tremolite may be even 10 feet or more. Tests of spinning and weaving properties can only be done by the manufacturers.

Barite.—Little or no deleterious material should be associated, so that an analysis of the barium sulphate content is essential; barium sulphate should not be less than 95%, and iron oxide not over 1%; for glass purposes iron oxide should be not over 0·1%. The finely ground powder should be pure white.

Bauxite.—An analysis of the alumina, silica, iron oxide, titanium oxide and water content is generally essential. For the manufacture of aluminium and alumina abrasives the silica should not exceed 3% but iron oxide may be up to 25%; for aluminous chemicals iron oxide should be less than 2%, and for refractories the iron oxide should be less than 1·5%. Apart from the manufacture of aluminium and chemicals, the properties of bauxite for other purposes can only be determined by actual use in small-scale tests.

Bentonite.—If a clay swells considerably in water and bentonite is suspected it may be further confirmed by shaking a crystal of benzidine in a suspension of the sample in water; a true bentonite gives a deep blue colour in less than five minutes, sub-bentonites give a blue colour or an indefinite green after some hours. The ultimate test for bentonite is X-ray analysis. However, actual small-scale application is the readiest means of determining whether a supposed bentonite can be used for a particular purpose.

Beryllium.—After the mineral is identified as beryl, the beryllium oxide content is determined by analysis and should preferably average 12-13%, certainly not less than 10%.

Bismuth.—The bismuth content only need be analysed but a test for the presence of silver is also advisable. Examination under the microscope will indicate the actual minerals present.

Borates.—A full analysis is generally necessary.

Building stones.—Physical tests of tensile and crushing strengths and wearing coefficients may be made at the Alipore Test House. Weathering tests may be made by actual exposure for several months under the severest conditions possible. Petrological examination at the Geological Survey will suggest the probable reaction of the rocks to changing conditions and their suitability for various purposes.

Cadmium.—All lead-zinc ores should be tested for the probable presence of cadmium.

Chromite.—As a general rule the ore is assayed for chromium oxide, ferrous and ferric oxides, magnesia, calcium, alumina, and silica. In India the ore is divided into grades according to the

chromium oxide content: first grade ore contains over 47% Cr_2O_3, second grade 44–47%, and third grade below 44% Cr_2O_3. Its suitability for refractory bricks can be determined only by actual tests at a firebrick works.

Clays.—For the manufacture of cement, firebricks and pottery, and for use as a filler, a full analysis is normally advisable.

For use in firebricks the clay should be plastic; small briquettes are made and heated, the softening temperature noted, the shrinkage measured, and physical properties (colour, strength) after heating observed. Defects in plasticity and shrinkage may, in some cases, be rectified by mixing with other clays.

White clays suitable for textile and paper filler, pottery and porcelain have often been rejected in India because they are gritty. This is a mistake, as the grit can be readily removed by washing. Tests should be made on the washed material, reduced to even 20% of the original quantity if necessary. The colour should be pure white, although for some purposes a slight creamy tint is acceptable. For filler the plasticity should be fair. For pottery the plasticity should be good, shrinkage low, softening temperature very high, the colour after firing white, and the briquette should be quite strong. The detailed testing of clays is a highly technical investigation.

Coal.—A proximate analysis of a coal indicates the percentages of water, volatile matter, fixed carbon, and ash; the determination of whether the coal is coking or non-coking is important. In some cases the sulphur and phosphorus content is required. The calorific value is also important.

Cobalt.—The cobalt content of the ore is estimated, and it is advisable also to determine the amount of gold, copper, and nickel present. A microscopical examination of the ore should be made.

Columbite and tantalite.—These are usually obtained only in small parcels, perhaps of only a few cwts and are sold on their niobium and tantalum oxide contents.

Copper.—In addition to copper, the ore should be assayed for nickel, cobalt, lead and zinc, and a concentrate assayed for gold and silver. If an ore-body is economically workable, a complete

analysis should be made of a representative sample before the ore is submitted for treatment tests. A thorough examination of many specimens under the microscope is essential to determine the various minerals present. Most sulphide copper ores contain between 1 and 4% copper. Hand-picked ores from small mines, and which have to be transported considerable distances, are unlikely to be payable under about 10% copper.

Diatomaceous earth.—This material is best identified under the microscope, which permits an estimate of the proportion of siliceous skeletons present. Further tests may include determination of specific gravity and bulk density, absorption capacity, grain size, chemical composition, and actual behaviour as a filtering medium and for other uses.

Feldspar.—The determination of whether the feldspar is orthoclase or plagioclase is a simple mineralogical examination, nevertheless, it is advisable to have a representative sample fully analysed.

Fluorite.—A full analysis is advisable as, for certain purposes, even small quantities of metals like lead, zinc, and copper may be deleterious. For steel smelting the calcium fluoride should be over 85%, and silica not more than 5%. For manufacture of hydrofluoric acid, the calcium fluoride should be over 98% and silica not over 1%. For use in glass and enamel, the calcium fluoride should be not less than 95%, silica not more than 3%, and iron oxide below 0·12%.

Fullers earth.—Non-plastic clays which do not disintegrate in water, and have the property of adhering to the tongue, should be tested to see whether they can be used as fullers earths and whether they have the power of bleaching (or decolourising) oils. In addition, tests may be made of volatile content, density, acidity, and particle size (screen analysis).

Gold.—In addition to determining the gold and silver content of an ore, it is advisable to determine whether part of the gold is in combination with other elements, such as tellurium, as this will affect the treatment. In India the minimum gold content of small veins should be about 4 dwts per ton of ore.

Graphite.—The sample should be examined to see whether it is flaky or amorphous graphite, and the carbon content then determined. Samples of lumpy graphite not uncommonly look deceptively rich because each lump may acquire a graphite coating, but when broken open it may be low grade. The presence of mica may cause difficulties in refining. The graphite content of the crude material may range from 35% upwards.

Gypsum.—An analysis of the hydrous calcium sulphate content is necessary; this should be about 90%, but lower grade material may also be used.

Iron.—A representative sample should be assayed not only for the iron content but also for alumina, silica, phosphorus, and sulphur. In India the iron content is normally required to be over 60%. In Europe, ores even below 30% have been mined, but many of these are self-fluxing and do not require limestone to be added to the furnace charge. Micaceous hematites may be tested for use in special paints.

Kyanite, sillimanite and andalusite.—An analysis showing alumina (over 60%), silica (less than 36%), iron oxide, calcium, magnesia, and titanium oxide is necessary. The iron oxide should not exceed 1·5%, and free silica (the amount not in chemical combination with alumina) should not exceed about 2%. United States consumers of Indian kyanite demand a more exacting analysis than is obtainable from their domestic deposits of these minerals—some kyanite-rock mined in the United States contains only 10% kyanite and has to be concentrated.

Lead.—Besides estimating the lead content, zinc and silver should also be determined. If these percentages are payable it is advisable to have a full analysis made on a representative sample, to include copper, antimony, arsenic, bismuth, nickel, cobalt, selenium, and gold. The minimum total lead plus zinc content should be of the order of 18–25%. Examination of the ore under the microscope will indicate the actual minerals present.

Limestone.—The rock should normally be analysed for calcium carbonate, magnesium carbonate, silica, alumina, and iron oxides. For certain purposes soda, potash, sulphur, phosphorus, manganese,

titanium, and water may also be determined. The analysis will indicate whether the limestone is suitable for chemical, metallurgical, cement or other purposes.

Limestone to be burnt for use in mortar and plaster need not be pure; a little clay may improve its qualities. In the manufacture of cement a certain amount of silica and alumina may be present in the limestone; magnesia should not exceed 2·0% and iron 2·0%. Limestone for iron and steel smelting may contain magnesia, but silica and alumina should be low. In glass manufacture the limestone may contain some free quartz and alkalies but magnesia and particularly iron are undesirable. A very pure limestone is essential in the chemical industries, relatively chemical inert material like quartz is not particularly detrimental, iron should be below 0·20%, alkalies must be low, and the combined impurities less than 1-2%.

Lithium.—The lithium-bearing mineral is analysed for its lithia content, but it is advisable to have a full analysis made of a new find. Lepidolite will contain 2–4% lithia; the iron content must be very low.

Magnesite.—Usually it is sufficient to determine the magnesia, lime, iron oxide and 'insolubles' content, but for a new material a full analysis should be made. Physical tests may be made for the suitability of the caustic calcined magnesite in oxy-chloride cements, and of the dead-burned magnesite for refractory purposes.

Manganese.—In India, manganese ore is graded as follows:—first grade ore, over 48% manganese; second grade ore, between 45 and 48% manganese; third grade ore, below 45% manganese. Chemical ore contains over 80% manganese dioxide. Some ores down to 32% manganese and with as much as 17% iron are sold to the iron and steel industry. Samples should be analysed for manganese, manganese dioxide, iron oxides, alumina, silica, phosphorus and sulphur. If the manganese dioxide content is over 80%, a full analysis should be made to determine its suitability for chemical purposes. Such 'dioxide' ore should also be submitted to the Alipore Test House to determine whether it is suitable for the manufacture of dry batteries. For the smelting of ferromanganese,

the phosphorus content should not exceed 0·3%. For glass manufacture the ore should be as free as possible from iron. For chemical purposes, although high grade dioxide ores are essential, impurities insoluble in acid are not particularly deleterious.

Mercury.—The sample requires to be assayed merely for its mercury content. The average ore in the United States contains less than 0·5% mercury and in Spain 8% mercury.

Mica.—As large a bulk sample as possible should be obtained from the deposit. The 'books' are then rifted, cut to remove the principal flaws, then sorted as to size and quality—quality is determined by the degree of staining and straining and can only be judged reliably by an expert. The proportions of the various qualities and sizes will give some idea as to whether the deposit is likely to be payable.

Mineral pigments.—If the ochres are somewhat gritty it is advisable to wash the crude material before testing. A rough test is to mix the ochre with clear linseed oil, spread it on a glass, and view the colour on the reverse side of the glass, comparing with standard colours if these are available. Most mineral colours are mixed with 10 to 20 times their weight of zinc oxide or white lead for use in paint, so that a good test is to mix the ochre with 10 times its weight of zinc oxide before comparing with similarly diluted standards. The ultimate test is, of course, submission to paint manufacturers, for only they are fully aware of what particular tints are required.

Molybdenite.—The ore should be assayed for its molybdenum sulphide content, and molybdenum oxide should also be determined as, if present, this will affect the treatment process.

Monazite.—The beach sands are washed, and the monazite concentrate assayed for its thoria content, which is generally 8–10%.

Nickel.—It is necessary to determine whether the nickel is present as a silicate or sulphide. If as the latter the ore should also be assayed for cobalt and copper. A concentrate of the sulphide should be tested for the presence of gold and the platinum group of metals. Microscopic examination is advantageous.

Nitrates.—The percentages of various nitrates, chlorides and sulphates present are usually required.

Petroleum.—The natural oils and gases are tested with the object of ascertaining what petroleum fractions are present. A crude oil is of either a paraffin, asphaltic or a mixed base; this determines the treatment to which the oil will subsequently be subjected and, to some extent, the refined products which may be obtained from it.

Phosphates.—Analysis of the tri-calcium phosphate content is essential, but for a new find a full analysis is advisable. The commercial range is 35% to over 90% tri-calcium phosphate. Singhbhum apatite averages 20–25% P_2O_5.

Platinum.—Specimens likely to be submitted simply as platinum would be of alluvial origin and would require merely to be identified as such.

Potash.—Salts containing potash require to be fully analysed.

Precious stones.—The identification of precious stones is advisedly left to the expert, who will determine them by tests of hardness, specific gravity, refractive index, birefringence, pleochroism and colour.

Radium and uranium.—Any specimen in which uranium is suspected should be tested for radioactivity by the electroscope. The uranium oxide content should be determined, and a full analysis then made.

Salt.—If an analysis of salt is required the sodium chloride, magnesium chloride, calcium chloride and calcium sulphate content are determined and perhaps also sodium, potassium and magnesium sulphates.

Sand and gravel.—Well-equipped laboratories carry out tests on specific gravity, grain size, percentages of clay, silt and organic material present, and absorption. Simple physical tests will determine whether a sand or gravel is suitable for constructional or foundry purposes. In mortars and concrete a clear sharp (*i.e.* angular) sand is preferred. Moulding sands are used mixed with other materials, and as used must have cohesiveness in order to retain the shape of the pattern, and must be sufficiently refractory

not to be fused by the molten metal. They must also be sufficiently permeable to permit the escape of gases given off by the molten metal. For iron a very high quality sand is not essential, a good cohesiveness is the main property. For steel castings a good quality fine sand is used with special binders. For casting aluminium, lead, copper, brass or bronze, particularly if great detail is essential, a very fine sand must be used with special binders. All foundries have their own moulding mixtures which are the result of considerable experiment. Filter sands should be free from clay and organic matter and the grains should be evenly sized. For abrasive purposes, such as in cutting and dressing stones and in sand-blasting, the quartz grains may be either rounded or angular. In the manufacture of silicon carbide and of ferrosilicon a pure quartz sand of even grain size is essential.

The pure silica sands for refractory and glass-making purposes are generally crushed from sandstones or quartzites. In glass sands the size of the grains should preferably average 0·4 mm in diameter. For high quality colourless glass the iron content should not exceed 0·02%. A detailed analysis is generally necessary and also a sieve test.

Silver.—Most sulphide ores should be assayed for their possible silver content.

Slates.—The slate must be tested for its ease of cleavage, pleasing colour, hardness, density, porosity, absorption, strength, and electrical resistance. It should also not be readily corroded by acid or alkaline solutions.

Sodium.—Salts known to contain sodium compounds may be tested for sodium carbonate and sodium sulphate.

Strontium.—The samples are analysed for their strontium sulphate or strontium carbonate content as the case may be. Celestite should contain over 90% strontium sulphate; strontianite over 80% strontium carbonate.

Sulphur.—Samples of natural sulphur and of pyrite are analysed for their sulphur content. It is advisable to determine whether arsenic is present as this is deleterious, and also bitumen as this prevents the use of sulphur for certain processes.

Talc.—Physical tests of colour, hardness, grain size and type of grain (rounded or flaky) are generally sufficient to determine whether a sample of talc is suitable for a particular purpose. Microscopical examination is advisable, and for refractory purposes a chemical analysis may be made.

Tin.—Determination of the tin content is all that is necessary as a rule. It is advisable to test vein or disseminated tin ores also for tungstic oxide, present either as wolfram or scheelite. Molybdenum, bismuth, antimony, arsenic and copper may also be present.

Titanium.—The sample of sand should be washed, and the concentrate assayed for titanium dioxide; this generally exceeds 50%, although in the unwashed sands it may be only 25 to 35%. Iron, silica, sulphur, and phosphorus are also assayed. The presence of monazite and zircon should also be determined as these would be recovered as by-products.

Tungsten.—Tungsten concentrates are generally merely assayed for their tungstic oxide content which should be 65–70%.

Vanadium.—The ore is assayed in terms of its V_2O_5 content. The actual mineral form in which the vanadium occurs must also be determined for the purpose of indicating the method of treatment. Different ores in various countries range from 2% vanadium oxide to as high as 20% vanadium oxide.

Zinc.—Besides estimating the zinc content the lead, copper, and silver should also be determined. In addition, zinc ores should be tested for cadmium.

Zircon.—Concentrates from ilmenite beach sands should be tested for the presence of zircon. Zircon concentrates may be tested for their zirconium oxide content.

CHAPTER V

PROSPECTING

In India there have not, in the past, been any representatives of the class of rugged prospectors such as have helped to found the mineral industries of America, Australia and Africa. Many of these men had a more than elementary knowledge of mineralogy, they suffered incredible hardships, incessant poverty dogged most of them throughout life, but they were spurred on by the hope of riches over the horizon. Few found their El Dorado but all were attracted by the freedom of the life—a freedom which cannot perhaps be found in any other way of living. Even to-day the writer still has pleasant memories of those earlier days when he worked on the tin and osmiridium fields along the White, Pieman, and Savage rivers of the West Coast of Tasmania.

The majority of these prospectors first set out to look for gold and in doing so found other minerals. Others have specialised in certain minerals, searching for and working small deposits of copper, tin, wolfram, etc., in limited areas. A few have cashed in on rich finds, others have given the search up whilst it has still been possible to change their occupations, but others have continued to old age making a precarious living on small finds, or have subsisted as 'fossickers' by turning over the gravels on old goldfields, their sharp eyes searching for 'colours' of gold; the writer whilst surveying on the Bendigo goldfields, many years ago, over a period of four months, picked up nearly $\frac{1}{4}$ oz of gold specks on the surface soil around the theodolite whilst waiting to take readings.

Although India has lacked the American and Australian type of prospector, she has been fortunate in certain men of grit and foresight, who had faith in the deposits which came to their notice and who founded such industries as the mica and iron and steel industries.

The mineral industry in India today has been founded partly on information accumulated during the past century by the Geological Survey, and partly on the energies of the prospecting departments of such firms as Tata Iron and Steel Co. and Bird and Co.

There seems to be some confusion in India as to what is the function of a Geological Survey. Its fundamental work is the steady detailed mapping of the whole country, on as large a scale as is possible at any particular time. During a normal field season of six months, the average geologist will map in detail between 300 and 500 square miles on the scale of 1 inch to 1 mile—if he converted himself into a mere prospector he could not cover one-tenth of that area. The primary object of his mapping is to delineate in detail the geology of India, and thus to limit the areas of search for particular minerals. During the course of this mapping—the ultimate foundation of India's mineral industry—mineral occurrences come to light and are recorded to await such time as transport communications or market requirements make them economic propositions. To the layman such steady mapping appears to be 'only of scientific interest', but the search for minerals is becoming an increasingly scientific matter.

A company may use the information acquired by the Geological Survey, or may have a mineral brought to its attention in various ways. It will then take out a prospecting licence over the area in question, sometimes of several square miles, and will proceed to prospect carefully every part of that area. The preliminary prospecting will be directed towards finding all surface indications of the particular mineral. In jungle country the prospecting geologist may make traverses of the area along lines at fixed intervals apart, with a row of men on either side of him, each trained to observe the mineral in question; as they move over the ground they halt when anything of interest is seen, and the find is examined. In this way the whole area may be closely combed. Particular attention should be paid to rivers and nallas, as it is there that outcrops are more likely to be found, especially of such bedded deposits as coal. Fragments of a mineral deposit may be shed down a stream, nalla or hillside, and may be carefully traced back to their source. Not

uncommonly the surface indications are already sufficiently understood, and close scouring of the area may not be essential.

The results of such a search are carefully mapped. For preliminary work topographical maps on the scale of 1 inch to 1 mile, published by the Survey of India, may be used—the more modern of these maps are reasonably accurate relative to their scale but the older maps published last century are commonly unreliable. For somewhat more detailed work in Reserved Forest areas, the 4 inches to 1 mile maps prepared by the Forest Department may be used where these are available. In some cases a still larger scale must be used in order to delineate outcrops or prospecting pits and to enable the details of the geology to be indicated. A simple method of preparing such a map is to set out a base line, aligned say north-south, placing pegs in the ground at fixed intervals. From each peg an offset is then set out at right angles east-west, and pegs put in the ground along the offsets at fixed intervals. With these pegs serving as reference points the outcrops and geology, nallas, pits, boreholes, etc., may be sketched in, and in a report reference may be made to any particular position by its coordinates, say S 860′ W 250′. In some cases it may not be advisable to carry out an early survey in such detail, and it may suffice to run a series of traverses with compass and tape, connecting up important points to be delineated. The larger the scale of the map the more detail can be added.

The search for particular minerals is partly governed by their geological associations; thus, certain minerals are known to occur only with sediments of a certain age, or in the vicinity of rocks of a certain type, and it is a waste of time to look elsewhere for them. Coal may be found in India only with rocks which are classed as either Gondwana or Tertiary in age. Chromite is found only in close association with ultrabasic igneous rocks.

Having obtained the surface indications of the presence of a mineral deposit, it is necessary to determine its extent, laterally and, within limits, in depth.

The lateral surface dimensions of a mineral deposit may be determined by a careful study of the outcrops, or by sinking shallow

pits or augur borings, or by cutting shallow trenches. Some idea of the deposit at a reasonable depth may be obtained by sinking pits or shafts or by boring; in hill country an adit may be driven below the outcrop, into the hill, until it cuts the deposit.

The precise method of prospecting the extent of a mineral deposit will depend to some extent on its form, and here a knowledge of the mode of occurrence, outlined in chapter III, will be of great importance.

Surface deposits, such as certain occurrences of manganese, bauxite and clay, are best prospected by sinking shallow pits to determine not only their lateral extent but also their depth.

Bedded deposits may be followed along their outcrop and exposed at intervals by means of shallow trenches. They may be examined for a short distance down the dip by means of small prospecting shafts if necessary, but, as a general rule, if a bed has a considerable lateral strike it may be taken also to have considerable persistence down the dip. Not uncommonly such bedded deposits are explored in depth by means of boreholes, but unless a complete core is obtained the information from boreholes is liable to be misleading in uncautious hands, both as to thickness of the bed and average grade of the mineral deposit. Such boreholes may, however, give valuable information as to faulting, folding or other structural features of the beds in depth.

Mineral veins or replacement deposits may be prospected in a similar fashion to bedded deposits, by means of trenches across the strike and by prospecting shafts down to shallow depths. In such cases boreholes are even more unreliable than in bedded deposits for, from their very mode of formation, mineral veins may be expected to vary widely in composition. It may be quite possible for, say, four boreholes to be put down along the line of a lode, and each to pass through a poor part of the deposit, thus condemning the latter—the converse is also just as likely to happen. In replacement ore-bodies, particularly, it is much safer to use the evidence of boreholes merely to demonstrate whether or not mineralisation persists in depth, and then leave actual underground development work to prove the grade of the ore-body.

The object of prospecting is to obtain some idea of the extent of the deposit. All such work costs money, of course, and the question naturally arises as to how far such prospecting should be carried. This is largely a matter of common-sense finance, leavened by a knowledge of the mode of occurrence and of mining methods. Certain small clay deposits in which only a very little capital may be invested obviously warrant only just sufficient prospecting to demonstrate that there is enough clay present to permit immediate mining; it would be absurd to spend considerable sums to demonstrate the full extent of the deposit, the actual mining itself will demonstrate that. On the other hand, a coal seam may be carefully prospected by boreholes to gain a thorough idea of the structure, and a fair idea of the reserves, before the actual capital is invested and mining commenced, as the development plan of the colliery will be largely governed by a prior knowledge of the structure of the seam. Or yet again, it is sufficient in the case of some mineral deposits, such as copper, lead-zinc, or gold lodes to demonstrate that, down to a certain depth, there is a certain minimum tonnage which at a presumed practical rate of mining, with a determined capital, will last, say, three or five years; experience indicates that the deposit will persist below that depth, and it would be an absurd waste of capital to attempt to prove at once the full extent of the ore-body down to its lowest limits even if it were practical.

The anxiety to prove the full extent of reserves in the prospecting stages of a mineral deposit has seemed at times a remarkable characteristic of some Indian geologists. In some cases it is a laudable anxiety, provided that the work can be done reasonably cheaply compared with the capital that is to be invested, but, in other cases, it has been surprising to find that geologists of many years' experience have been unable to appreciate that the very principles of mining are not in favour of expenditure beyond that necessary to demonstrate the existence of reserves sufficient for a limited period.

It will be apparent from the above that prospecting may, in certain deposits, merge into actual development. This may be the case where shafts have actually to be sunk to some depth or

adits driven into hillsides in order to prove reserves or even the existence of mineral, as in the case of copper or lead-zinc deposits below old workings. The same shafts, and drives off them, may then be used for the actual working of the mine. In mica mining prospecting work quite commonly merges into actual development operations.

During the last twenty years various geophysical methods of prospecting have been tried in different parts of the world. These methods each measure certain physical anomalies in the rocks of the crust—the anomalies may be magnetic, electrical, gravimetric, or seismic. The geophysicist interprets these physical anomalies at any particular place in terms of the geology—structure and rock types. The popular impression that mineral deposits can be found by one of the methods of geophysical prospecting is incorrect, such methods can *only* indicate the positions of electrical or other physical anomalies and the positions of these anomalies may or may not coincide with mineral deposits. It will be appreciated, therefore, that geophysical methods are restricted in their application. At present it is not possible to apply them to wide areas in which the geology is little known; their principal application is in limited areas, already known to be mineralised, in which it is desired to locate hidden mineral deposits, or in which it is desired to trace the lateral extensions of known deposits. It is obvious also that, to be of value, there must be a well-defined difference between the physical characteristics of the mineral deposit and of the surrounding country-rocks, sufficient to give rise to easily recognisable magnetic, electrical, gravimetric or seismic anomalies as the case may be—anomalies of a type distinguishable from those which occur between individual members of the country-rock. Up to the present these methods have been of value in simple types of ore-bodies occurring in rocks which show little variation, within known ore-fields, such as deposits of magnetite which show a strong magnetic anomaly in gneisses, or of large bodies of sulphides which show a distinctive electrical anomaly in granites or gneisses. Where the mineral deposit contains little of the valuable mineral, and where the

anomalies between the deposit and country-rocks are no more pronounced than those occurring between the individual rock types of the associated country-rocks, as in the case of mica deposits for example, there the application of geophysical methods is inadvisable. Geophysical methods have been applied more widely and usefully in oil prospecting than in any other mineral prospecting. In its application to oil, however, the object of the geophysical investigation is not the direct detection of anomalies due to the presence of oil, but the interpretation of the structure of such geological strata as may be favourable to the accumulation of oil. It is generally used as an adjunct to other geological work.

A primary aim in prospecting a deposit is to obtain a fairly sound idea of the average grade of the mineral. Only too often, in certain types of deposits, the material cropping out and examined in the early stages is highly promising, but as exploratory work progresses it may be found that the best material was in the outcrops and that most of the remainder of the deposit is of lower grade. Caution cannot be too strongly emphasised against the hasty judgement of a deposit from one or two promising outcrops of high grade.

It will be apparent from the above that the amount spent on prospecting may vary enormously according to circumstances. Trenches are the cheapest form of prospecting; they may be cut for a few rupees each. Shallow pits or shafts will vary in cost according to the hardness of the rock and to whether or not timbering is necessary. Pits in soft material, not requiring timber, may be sunk for as little as Re1 per foot of depth, but if hand drilling is necessary costs may mount to over Rs10 per foot. Boreholes will vary in cost according to the rock, and the diameter and depth of the hole, generally averaging between Rs5 and Rs7-8-0 per foot for small core drills; on the coalfields Rs15 per foot is charged for a 6-inch hole down to 200 feet and an extra rate for greater depths. Shallow holes bored with an augur down to, say, 20 feet may cost only Rs2 to Rs3. Geophysical prospecting is generally done on contract, and charges for a working party by a geophysical prospecting company may be as much as £30 to £50 per

day—obviously, for a mining company with a competent staff capable of using geophysical apparatus the cost will be much less. The employment of geophysical apparatus by the Geological Survey would be advantageous in some investigations.

Abrasives.—Corundum and garnet deposits when found do not warrant any expensive prospecting, but may be mined at once according to market requirements. Practically all other mineral abrasives are of the bedded type, they crop out readily at the surface, and their presence is evident without the necessity of considerable expense to prove reserves.

Antimony.—Should a vein of antimony be discovered, trenches across the strike and an inclined shaft down the dip will provide some idea of the extent of the vein.

Asbestos.—Where associated with magnesian limestone, trenching may be done to indicate the trend and abundance of the mineral, and an inclined shaft may be sunk or boreholes put down to prove its persistence in depth; such asbestos deposits may be treated similarly to bedded deposits. If the asbestos is associated with basic igneous rocks the surface extent and amount of asbestos per ton of rock may be proved by shallow pits, which may be extended into open-cuts during actual mining.

Barite.—Shallow trenches across the line of vein should be sufficient to prove a barite deposit. Persistence in depth may be proved either by boring or by an inclined shaft down the vein—the latter is preferable.

Bauxite.—Bauxite boulders may be found in streams, leading to examination of the hills above. The majority of bauxite deposits in India crop out along scarp faces, just below a capping of laterite—such places should always be carefully examined for the presence of bauxite. When found, a series of small pits should be excavated on the plateau, through the laterite; the lateral extent and depth of the bauxite can also be rapidly ascertained by boring with an augur.

Bentonite.—If it is necessary to prove the extent of a bentonite deposit this may be done either by sinking pits or by means of an augur, whichever is the more suitable to the circumstances.

Building stones.—As the majority of building stones crop out and are bedded (except the igneous rocks), there is generally nothing to be gained by detailed prospecting, and quarrying can be commenced at once.

Chromite.—Chromite deposits are found either within or close to basic igneous intrusive rocks. When boulders of chromite, or chromite sands, are found, these may be traced to their source by examining the rocks upstream or uphill, resorting to trenching if necessary to expose the rocks below the surface soil. The strike of a vein may be determined by a series of trenches.

Clays.—Sufficient information can generally be obtained of the extent of alluvial clays by sinking a few pits which can then be expanded into quarries according to the configuration of the ground. Fireclays are generally bedded, a few trenches will rapidly indicate their persistence under soil cover—their persistence in depth can be normally taken for granted, but it is as well to sink a shallow shaft to determine whether there is any profound change in the clays below the weathered surface. China clays generally occur in granite country and may be irregular in form and perhaps partly under a soil cover; apart from sinking a trench or two to indicate that there is sufficient to warrant opening up the deposit it is inadvisable to spend money needlessly attempting 'to prove reserves'—the ramifications of such a deposit will become evident as quarrying proceeds. In some cases useful information may be obtained by means of an augur.

Coal.—Outcrops of coal seams should be carefully mapped and, where the soil cover is thin, the seams may be traced by shallow trenches. The careful examination of nallas may bring to light outcrops of seams. At depth, boreholes will indicate the dip and, under certain circumstances, may suggest the presence of faults, thus providing evidence upon which to base the choice of position of the shaft and lay-out of the mine development workings—such work is, of course, necessarily left to expert mining engineers.

Cobalt.—As in other vein-types, trenches and a shaft or adit should suffice to prove whether a cobalt vein is worth developing.

Copper.—A copper vein may be proved at the surface by trenching, and a prospecting shaft sunk, if possible, down to the primary sulphides will give information of its possibilities in depth. In India, as all the known veins have been already worked by the ancients, it is necessary to sink down through the old workings and drive along the lode to obtain any idea of the width and grade of the ore. Boreholes will demonstrate whether mineralisation persists in depth but will not provide reliable information as to ore values. Once the existence of ore within a reasonable depth is demonstrated the prospecting stage is left behind and the reserves on which the mine is to be based—sufficient for 3 to 5 years—should be developed. In certain types of mineralisation, such as the porphyry copper deposits of America and the remarkably regular and persistent deposits of Northern Rhodesia and Belgian Congo, boreholes may be quite safely used to determine the reserves available.

Diatomaceous earth.—These are bedded deposits and may be proved if necessary in a manner similar to coal. The better portions of the deposit may be determined by microscopical examination.

Feldspar.—This type of vein deposit requires no further prospecting than the sinking of a pit, which may be widened into an open-cut or extended as a shaft.

Fluorite.—The lateral extent of the deposit may be proved by trenching and careful sampling. If a treatment plant is necessary the demonstration of a minimum quantity of reserves is essential. It can usually be taken for granted in this type of deposit that the absolute minimum depth will be one-quarter of the length, and the presence of such minimum reserves is best proved by means of a shaft. The majority of such deposits are likely to persist to greater depths than their length, but the development of reserves in depth is best left to the future, when it becomes a charge on revenue.

Fullers earth.—A few pits at well-chosen sites should suffice to prove the extent of a deposit of fullers earth.

Gold.—As is the case with copper, the majority of gold veins in India have been worked by the ancients, and they can be prospected only by clearing out the old workings. Once the existence of payable gold is proved the risk must be taken and

reserves developed at once, at the same time a small mill should be installed, preferably one capable of expansion if later reserves prove this to be necessary. Of the alluvial deposits so far discovered in India and worked by villagers, none are dredging propositions such as would attract a modern mining company. A modern dredging plant to be payable would require approximately three grains of gold per cubic yard over a shallow valley covering at least several hundred acres, and with an adequate supply of water.

Graphite.—Where small boulders or flakes of graphite are found, these should be traced to their source. Small nallas may be followed, and where graphite is seen in the soil along a nalla bank, the soil should be trenched and the graphite followed uphill to the vein, bed or segregation. The lateral extent of the deposit may be determined by trenches, and the depth by pits.

Gypsum.—Where gypsum is obtained from clay-beds, the gypsum content can be ascertained from a few pits. Where the gypsum forms massive beds which crop out, as in the Salt Range, mining can be commenced with little or no preliminary prospecting.

Iron.—Outcrops of hematite should be carefully mapped; the geologist can readily judge whether the deposit is of the type which is likely to persist in depth and this can be checked by boring if necessary. On determining the area of outcrop the geologist will assume a certain minimum depth according to the characteristics of the deposit, say 50 feet, and thus calculate the reserves. Veins or segregations of magnetite may require to be proved by trenches or pits.

Kyanite.—The kyanite deposits of India are of a type which are not susceptible to detailed prospecting in order to prove reserves accurately; most consist of residual boulders at the surface and in the soil cover. Sillimanite deposits normally crop out and can be readily mapped, permitting a minimum tonnage estimate—in making this estimate caution should be exercised as although sillimanite boulders may crop out over a wide area much of the intervening material may be found, on excavation, to be kaolinised.

Lead.—Trenching and shaft sinking are generally required during the prospecting stages of a lead deposit.

Limestone.—Most limestone deposits are bedded. It usually suffices to cut trenches across the bed in order to secure representative samples of the limestone for analysis. Core drills may provide useful information in some cases.

Lithia.—Should lepidolite deposits in India be opened up their extent may be proved primarily by trenching and shaft sinking or boring.

Magnesite.—Pits, from which representative samples may be obtained, suffice to prove minimum figures for reserves.

Manganese.—In jungle areas known to contain manganese, the whole area may be closely combed for manganese indications. These may be proved by trenches or pits. In manganese-bearing regions partly covered by a widespread soil-cap, as in the Central Provinces, it is probable that magnetic or electrical geophysical methods may be used in the future to locate new deposits.

Mercury.—Trenching and shaft sinking would be necessary to prove cinnabar deposits should any be found in India.

Mica.—Mica pegmatites appear to be found only within mica-schists, or gneisses derived from mica-schists. Where the mica pegmatites crop out at the surface the presence or absence of payable mica can be determined by surface excavations, and these may merge into normal mining operations. In country where the underlying rocks are blanketed by a soil cover, the presence of a mica pegmatite may be suggested by flakes of mica in the soil, and this evidence can then be followed by excavating pits or trenches. Segregations of phlogopite may be exposed in the same way; in hill country the sides of nallas may be closely examined and abundant flakes of mica may be followed by excavating the soil uphill. In examining known phlogopite-bearing country for new deposits attention should be paid more particularly to certain rocks known as 'pyroxenites'.

Mineral pigments.—Generally, the value of a red or yellow ochre deposit does not warrant more expenditure than that necessary to sink one or two pits, sufficient to demonstrate that the quality is suitable and that there is enough available to permit mining.

Nickel.—Should deposits of nickel be found in India they may be prospected by the usual trenches and shafts.

Petroleum.—The amount spent in the search for oil throughout the world probably far exceeds that spent in the search for all other minerals together. In the oil industry of today a large proportion of the total expenditure is entailed in actual prospecting work, and a large company may spend hundreds of thousands of pounds unsuccessfully in a particular area. It is obvious, therefore, that oil prospecting should be left to companies with considerable capital at their disposal.

The presence of oil-bearing rocks within a region is usually, but not invariably, indicated by the occurrence of oil-seeps or gas shows at the surface. An oil-seepage does not, however, certainly indicate the presence of an oil-field; on the contrary, seepage usually occurs where the oil-bearing bed crops out at surface under conditions which preclude the accumulation of oil and gas under pressure. Such occurrences afford important information to the geologist as to the bed or beds in the rock sequence which may prove oil-bearing under suitable sub-surface conditions. The locating of suitable structures demands the mapping of the whole region, nowadays usually by aerial methods, followed by detailed large-scale surveys over the more favourable areas. The site for the first test well is selected near the crest of a dome structure in which the oil-bearing beds are within reach of the drill. Exceptional wells may reach over 15,000 feet in depth.

If the geology over part of a supposed oil-bearing region is obscured by alluvium, the help of the geophysicist is obtained; under suitable conditions, for example in the Gulf Coast of America, a large number of new oil-fields have been discovered by geophysical methods.

The rock structure at depth may differ considerably from that seen in surface outcrops and all possible information is collected from cores taken from the test wells. Such information is usually sufficient to correlate the rock beds from one test well to another and with the rock sequence in the area; by such means the exact

underground structure is determined and a development programme can then be laid down.

Phosphates.—Veins of apatite, such as occur in Singhbhum, may be prospected by trenching and drilling. Sedimentary rock phosphates are unknown in India, but phosphatic nodules which occur in surface clays in Madras are collected.

Precious stones.—Apart from such large deposits as the diamond-bearing 'blue ground' of South Africa, and some of the alluvial deposits of Africa, most deposits of precious stones are small and haphazard—mining is really a matter of continuous prospecting in which any attempt 'to prove' reserves would be misplaced energy and a waste of money. On the extensive alluvial deposits in Africa, however, the large companies block out and prospect the gravels by test pits before mining.

Sand and gravel.—Sand and gravel deposits occur generally, of course, in flat alluvial areas, but beds interstratified with other rocks may also be used. Once located, a few pits will demonstrate whether the material is suitable and the supplies extensive. If, however, the sands are required to conform to a precise specification, careful sampling should be done in a large number of pits. The suitability of beds of sandstone or quartzite for special sands may generally be determined from the outcrop; although excavations may indicate whether there is any change below the weathered outcrops, an idea of the extent may be obtained from the outcrops alone.

Slate.—After examination of the outcrop and an excavation into the fresh slate below the weathered surface to determine its quality, further prospecting is unnecessary.

Strontium.—The segregations of celestite in surface soils are located by close examination of the soils and by sinking shallow pits. In England iron rods are pushed into the soil in order to locate the hard lumps of celestite.

Sulphur.—A natural sulphur deposit may be prospected by a close examination of outcrops and by sinking pits at suitable points to determine the lateral extent and, if possible, thickness of the deposit and depth of overburden. In America geophysical methods

of prospecting are used in known sulphur regions to locate large deposits, and these are then proved by diamond drilling.

Talc.—Shallow surface excavations normally suffice to prove the quality of the talc and provide some idea of its lateral extent; expenditure on excavations to determine depth limits are needless. The surface excavations can be expanded into open-cuts during quarrying.

Tin.—Cassiterite veins may be prospected by trenches and inclined shafts as for other veins. Alluvial deposits are prospected by boring through to bedrock, the borehole samples being carefully measured and washed, and the washed concentrates assayed. The assay results are quoted in lbs per cubic yard.

Titanium.—Ilmenite-bearing beach sands are carefully examined to obtain an idea of their extent and, if necessary, excavations are made to determine their thickness and the depth of overburden.

Tungsten.—Both wolfram and scheelite occur in veins and may therefore be prospected by trenches and inclined shafts. Residual deposits may be prospected in the same way as for tin—tin and tungsten commonly occur together—but alluvial wolfram deposits, once found, may be worked without extensive exploratory investigation.

Vanadium.—The vanadium-bearing ironores of India crop out at the surface. In these ore-bodies the difficulty will be to locate the parts which are high grade, and this can be done only by very close sampling.

Zinc.—As in other veins, zinc deposits may be prospected in the initial stages by trenches and inclined shafts or adits. Because of the surface alteration which takes place in sulphide veins of this type, inclined shafts or adits to below the water table are likely to provide the most reliable information.

CHAPTER VI

SAMPLING

The correct taking of representative samples is of importance in many industries and more particularly in mining. The methods of sampling to be adopted in various circumstances have received the close attention of many mining engineers. All mines of importance have a staff for this work, and the most suitable method is generally developed for each mine. We are concerned here with simple types of deposits which are likely to be worked in a small way in India.

Sampling is undertaken at all stages in the investigation and mining of a mineral deposit. During the exploratory period samples may be taken merely from the outcrops in order to gain from the analyses some idea of the likely grade of the deposit. During the prospecting period the object is to determine the average values in the accessible parts of the deposit, and, in some cases, to determine the payable areal limits of the deposit. During the development stage, when reserves of ore are blocked out prior to mining, samples are taken at regular intervals in order to determine the exact grade of ore at each part of the deposit, thus indicating the positions of rich and poor ore for mining control. The mined ore is also sampled before despatch, or before treatment, generally by taking grab samples from the ore-trucks, or by taking a cut across the finely crushed ore at definite time intervals as it comes from the grinding mills. As it passes through various stages of treatment, the mineral may be further sampled at each stage in order to provide control of the various processes, and the final product is sampled before sale.

The object in sampling is to gain as accurate an idea as possible of the composition of the mineral deposit at any particular place. For practical purposes the sample is regarded as representing a certain zone surrounding the position of the sample, hence the sample should be taken in such a way that it is as representative as

possible of mineral around it. If the composition of the deposit varies only very slightly throughout its volume, then each sample may be representative of the mineral within a wide radius, but if the composition varies considerably within very short intervals, then the sample can be representative of the mineral within only a small radius—there are instances in which the composition ranges over such extreme limits within very short distances that only extensive bulk samples can be accepted as representative. It will be apparent, then, that the permissible space interval between samples will be governed by the degree of regularity of distribution of the important constituents throughout the mineral deposit.

Not uncommonly a specimen may be submitted to the Geological Survey of India with the assurance that it is representative of a particular mineral deposit. In some cases the analysis of such specimen will indicate whether the mineral deserves further investigation. In other cases, such as of copper or lead minerals, the layman may submit the best-looking specimens which he can find, whereas the actual deposits may consist of quartz with rare patches of metallic minerals and be of no value whatever; analyses of such misleading specimens would give no useful information. Samples taken during reconnaissance or exploratory work should be as representative of the workable outcrop as possible.

In mining, five main types of samples are taken: chip, groove, bulk, borehole and grab samples.

Where a deposit is more or less homogeneous both in structure and composition across its width, small chips may be knapped off at close regular intervals to make a collective sample across the width. The method may also be used on hard dense ore which crops out over a wide area.

The most general method of taking samples is by cutting a 3″ by 1″ groove across the width of the deposit. In cutting such samples care must be taken to eliminate any tendency to take more of the soft part than of the hard part of the mineral aggregate. Hard and soft portions should be taken equally and impartially. On cutting, some minerals break up readily to a fine powder and may be lost—care should be taken to include as much of this as possible

in the sample. A clean strong sheet should be spread out below the groove whilst cutting, and the sample collected on the sheet.

Where the grade of a deposit is known to be variable, large or bulk samples may be taken, such as the whole of the material removed from a trench, which is then 'coned and quartered' (see below) down to a reasonable size. In some cases the grade may be so extremely variable that bulk samples of several hundred tons of the mineral may be taken from a mine and actually treated before any reliable information is obtained as to the average yield.

As remarked on page 67, borehole samples are not, as a rule, reliable unless the deposit is very regular in composition. Where the whole of the core is obtained this may be cut longitudinally, and one-half assayed. The cuttings or sludges are also collected and assayed, but inaccuracies are liable to creep in as the sludge settles out from the borehole water.

Grab samples are generally taken only during the working of a mine, either from wagons or from dumps. In the first case a piece may be taken from each wagon. In the second case the samples are drawn according to a regular pattern over the dump.

To reduce any sample to a suitable size for despatch and assay it is 'coned and quartered'. The pieces are first broken to a reasonable size depending upon the volume to be reduced and piled into a flat cone which is then divided into quarters; opposite quarters are rejected, and the process repeated on the remainder. As the sample is reduced in volume so also should the size of the pieces be reduced; thus an original sample of 100 lbs should be in pieces of 1″ maximum size, reducing for each quartering until at, say, 5 lbs the maximum size should be rather less than ¼″. During coning and quartering care should be taken that the fines are equally distributed. Mechanical methods of quartering are also used.

Not uncommonly a deposit may consist of several grades of a mineral: first, second, and third grade. The samples may permit of the areal delineation of the reserves of each grade available.

It may also be necessary to determine the percentages of other constituents present in each sample. For example, in iron ore,

besides iron the content of silica, alumina, phosphorus, and sulphur may be estimated; in limestone, calcium, magnesia, alumina, iron, and silica are required; in coal, fixed carbon, volatiles, ash, and moisture are determined. The average percentage for each of these is estimated as in the examples given below, and the average composition of the whole thus determined.

In certain minerals samples are required not for actual chemical analysis but for physical tests. Clays and mineral pigments may be merely tested for their physical suitability for certain purposes.

In the case of some minerals which are used in their natural state, such as mica and asbestos, a deposit is prospected to indicate whether the mineral is present in sufficient abundance to be worth developing thoroughly. Prospecting will then have as its object the extraction of bulk samples which may be actually marketed.

Some simple cases of sampling during prospecting and development may be discussed.

Example 1.—A deposit of titaniferous iron oxides crops out over a certain area. It is known that this contains a very variable percentage of vanadium oxide and it is desired to know whether the deposit may be of value for its vanadium oxide content. About a million tons are known to crop out at the surface, so that operations could be commenced if the grade of vanadium oxide is high enough (it is assumed that a process for treatment is available), and there need be no concern at present with the persistence of the deposit in depth. The samples are required for two purposes: (*a*) to determine the average composition of the ore, and (*b*) if the average composition is below economical grade, to determine which part of the ore-body is of sufficiently high grade.

The deposit should be surveyed and divided into squares, 100 ft. by 100 ft., pegs being inserted at the corners of each square and the latter designated by numbers. For a deposit in which the grade does not vary widely, a chip sample from the centre of each square would suffice to represent that square. But in the present case the composition varies within close intervals, so that to obtain

a representative sample of each square small equal-sized chips of ore should be taken at, say, 10 ft. intervals in each square. The chips from each square should then be mixed together and 'coned and quartered' down to about 5 lbs in weight.

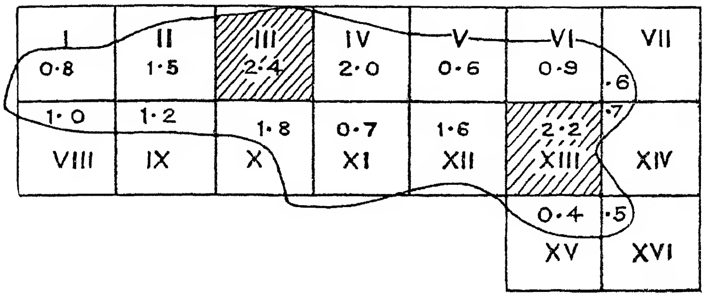


FIG. 10. Surface sampling of a deposit.

The *average* vanadium content of each square is now known after the samples are assayed, and the average assay of the whole deposit may be readily calculated. But, as the annual demand for vanadium is small—a deposit yielding less than 100 tons of metallic vanadium a year would be excellent—it may be desirable to mine only the highest grade surface patches at first and leave the lower grade material to the future when technique will be improved. To find these high grade patches, the squares which show the highest

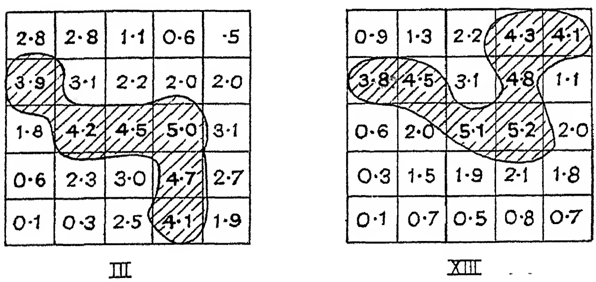


FIG. 11. Delineation of high grade ore.

average values are now selected and subdivided into 20 foot squares, and representative chip samples taken from each at close intervals in the same manner as before. The resulting assays will indicate where the highest grade ore may be obtained.

Example 2.—In certain cases it is essential to know the depth of the deposit, which also may not crop out noticeably. For example, bauxite may crop out over a small area roughly 500 feet by 300 feet. The cost of sampling and of analyses is by no means inconsiderable and it may be essential to keep the number of samples down to a minimum. In the first instance five samples may be taken, one at each corner, say 50 feet from either edge, and one approximately in the centre. Pits would be dug to go right through to the base of the deposit, or in some cases boreholes may be used—if the bauxite is soft it may be practicable to use an augur. A representative sample, a groove 3 inches wide and 1 inch deep, is cut from top to bottom of the bauxite in each pit; if the pits are small the whole of the bauxite excavated from each may be coned and quartered. In the case of bore-cores these are split longitudinally, and one-half used for assay. If, on analysis, the five samples are found to show no important variation between each other, then they may be taken as representative of the ore-body as a whole. If the assays vary widely more samples must be taken, say at 100 foot intervals, each sample being representative of a 100 foot square.

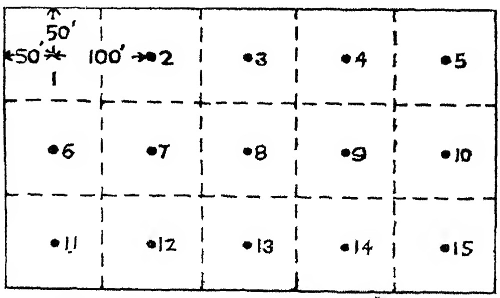


Fig. 12. Sampling a deposit by pits.

The details of each sample may be then tabulated as in the Table 2.

TABLE 2.

No.	Depth (feet) Top.	Bottom.	Thickness T.	Percent Al_2O_3 P.	Weighted percent, $T \times P$.
1	4	11	7	55	385
2	3	9	6	58	348
3	1	9	8	60	480
4	2	7	5	55	275
5	3	9	6	57	342
6	3	12	9	62	558
7	6	14	8	64	512
8	5	15	10	66	660
9	4	13	9	65	585
10	5	13	8	63	504
11	8	18	10	68	680
12	7	20	13	67	871
13	6	22	16	66	1056
14	7	21	14	66	924
15	7	19	12	67	804
	71		141		8984

$$\text{Average assay value per cubic foot} = \frac{8984}{141} = 63{\cdot}7\%.$$

$$\text{Average thickness of deposit} = \frac{141}{15} = 9{\cdot}4 \text{ feet.}$$

Total volume $= 150{,}000 \times 9{\cdot}4 = 1{,}410{,}000$ cubic feet (probably 100,000 tons).

$$\text{Average depth of overburden} = \frac{71}{15} = 4{\cdot}7 \text{ feet.}$$

Examination of the pits or bore-cores may show that the deposit varies considerably in depth. Separate samples will then be taken in each pit to represent the various layers of bauxite. Assays of only those layers which can be payably mined will appear in the above table.

Example 3.—It is not always possible to obtain the samples at regular intervals, perhaps because of the surface configuration of the ground; in this case the samples have to be weighted according

TABLE 3

Δ No.	Sample No.	Thickness. T.	Percentage Mn. P.	$T \times P$.	Av. Perc. Mn. P_a.	Average thickness.	Area of Δ A	Vol. of Prismoid V.	Total Perc. $V \times P_a = P_v$
A	1	4	47	188	$\frac{929}{19} = 48 \cdot 9$	$\frac{19}{3} = 6 \cdot 3$	6600	41580	2033262
	4	3	47	141					
	5	12	50	600					
		19		929					
B	1	4	47	188	$\frac{880}{18} = 48 \cdot 9$	$\frac{18}{3} = 6$	10350	62100	3036690
	2	2	46	92					
	5	12	50	600					
		18		880					
C	2	2	46	92	$\frac{1202}{24} = 50 \cdot 1$	$\frac{24}{3} = 8$	11050	88400	4428840
	5	12	50	600					
	6	10	51	510					
		24		1202					
D	2	2	46	92	$\frac{746}{15} = 49 \cdot 7$	$\frac{15}{3} = 5$	7600	38000	1888600
	6	10	51	510					
	3	3	48	144					
		15		746					
E	3	3	48	144	$\frac{748}{15} = 49 \cdot 9$	$\frac{15}{3} = 5$	6650	33250	1659175
	6	10	51	510					
	7	2	47	94					
		15		748					
F	4	3	47	141	$\frac{879}{18} = 48 \cdot 8$	$\frac{18}{3} = 6$	8050	48300	2357040
	5	12	50	600					
	8	3	46	138					
		18		879					
G	5	12	50	600	$\frac{780}{16} = 48 \cdot 8$	$\frac{16}{3} = 5 \cdot 33$	8925	47570	2321416
	8	3	46	138					
	9	1	42	42					
		16		780					
H	5	12	50	600	$\frac{1152}{23} = 50 \cdot 1$	$\frac{23}{3} = 7 \cdot 67$	12400	95108	4764911
	6	10	51	510					
	9	1	42	42					
		23		1152					
I	6	10	51	510	$\frac{596}{12} = 49 \cdot 7$	$\frac{12}{3} = 4$	8800	35200	1749440
	9	1	42	42					
	10	1	44	44					
		12		596					
J	6	10	51	510	$\frac{648}{13} = 49 \cdot 8$	$\frac{13}{3} = 4 \cdot 33$	6650	28795	1433991
	7	2	47	94					
	10	1	44	44					
		13		648					

Total volume = 518303 cu. ft. (probably 51,800 tons).
Average assay = $P_v/V = 49 \cdot 53\%$.
Average thickness = $V/A = 5 \cdot 95$ feet.

to the radius of influence which each represents, before the average value can be calculated. For example, a manganese deposit may have been prospected by several pits scattered at irregular intervals.

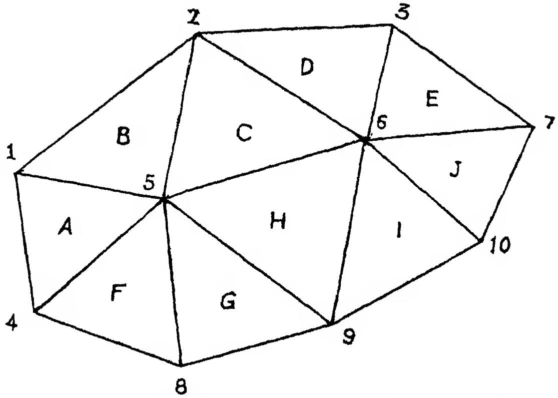


FIG. 13. Samples taken at irregular intervals.

The distances between the pits are measured and plotted (Fig. 13), and on the plan the area of the deposit is divided into triangles by connecting each pit. Each triangle is represented by the samples at the three corners, and for each triangle the average assay value is calculated from the sample assays weighted according to depth; the over-all average assay is calculated from the triangle average assays weighted according to volume. The results are tabulated as in Table 3.

Example 4.—The last method gives the average assay *within the area enclosed by the samples.* In most cases, however, it can be reasonably assumed that the ore extends some distance out from the positions of the sampled pits, or perhaps the actual boundaries of the ore-body may be known. The basic principle is again to weight each sample according to its area and volume of influence. The line joining each sample position is bisected by a perpendicular, thus dividing the area into polygons (Fig. 14). Each polygon represents the area of influence of each sample. The area of each polygon may be determined by means of a planimeter

or by plotting on graph paper. The volume (V) of each polygon is then determined, and the weighted percentage of each will be

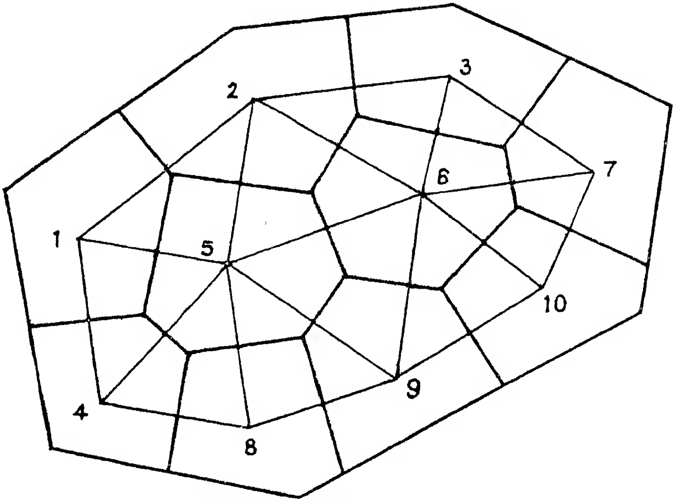


FIG. 14. Polygonal division of sampled area.

calculated, $V \times P$ as before. The total $V \times P$ of all the polygons, divided by the total volume, will give the percentage of manganese. The total volume divided by the total area will give the average thickness.

Example 5.—Many deposits occur as lodes or veins, or as thin beds, which may be of narrow width but of considerable strike length, and which may dip at any angle up to the vertical. In the prospecting stage such deposits may be exposed in only small outcrops, or in trenches, shallow pits, or small prospecting shafts. Samples can then be taken only from such places as are accessible, but wherever possible samples should be taken across the full width of the vein or bed. In some cases, however, one side or other of the vein or bed may be obviously so poor as to be unpayable, and it may be practicable to avoid removing such unpayable material during later mining; the samples should then be taken in sections across the lode or bed, the width of lode or bed represented by each

sample being carefully noted (Fig. 15). The samples may be taken by coning and quartering all of the material removed from each

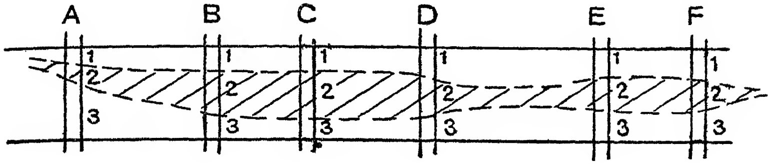


FIG. 15. Sampling a lode outcrop by trenches.

trench, provided that the depth of ore in each trench is the same along the full length of each sample. Alternatively, a groove, 3″ by 1″, may be cut along the side of each trench. Each sample represents a length of lode (or bed) half-way between itself and the trenches on either side. If the trenches are at equal distances apart the assay values are weighted merely according to the length of each sample, but if the trenches are at unequal distances each sample must be weighted according to the surface area which it represents, and the average assay calculated from the weighted figures. The average width can be calculated from the total surface area divided by the total strike length, or, in the case of evenly spaced trenches, by a simple average of the sample lengths.

Example 6.—In a deposit which is developed underground and divided into blocks by means of levels, rises, and winzes, sampling will provide information not only of the change in values along the strike but also in depth, permitting a more accurate determination of the average assay value. Obviously the accuracy of the estimates for each block will depend upon whether one, two, three or four sides of the block are exposed for sampling. If the four sides are available then the average value can be estimated with considerable accuracy.

In sampling a vein or bed, channels are cut across the width. Where the vein or bed is inclined (Fig. 16), the average thickness in the level, Ta, may be much greater than the true thickness, T—care must be taken to measure the true thickness. Also, according to the curve of the sides and roof of the level, and to the flat or

sharp angle at which the vein or bed meets the roof and side of the level, so will the length of sample, *a*, *b*, *c*, *d*, taken from each part

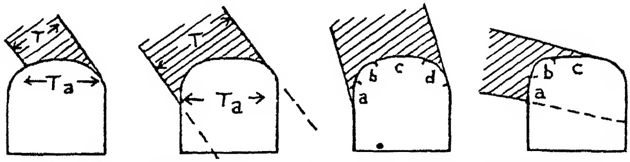


FIG. 16. Effect of dip on vein width exposed by level.
T = true thickness.
Ta = apparent thickness.
a, *b*, *c*, *d* = sample sections.

of the width of the vein or bed vary. In order to avoid obtaining disproportionate amounts of rich or poor parts of the vein or bed in each sample, the volume of the groove will be made to vary in each section, *a*, *b*, *c*, *d*; a wide or deep groove is cut where the groove is at right angles to the dip, and a proportionately narrower or shallower groove on that part of the roof or sides which is at an acute angle to the dip.

In some cases, as a level is being driven along the lode, samples may be cut across the width where it is exposed in the end face of the level. Where the samples are taken at the face at the end

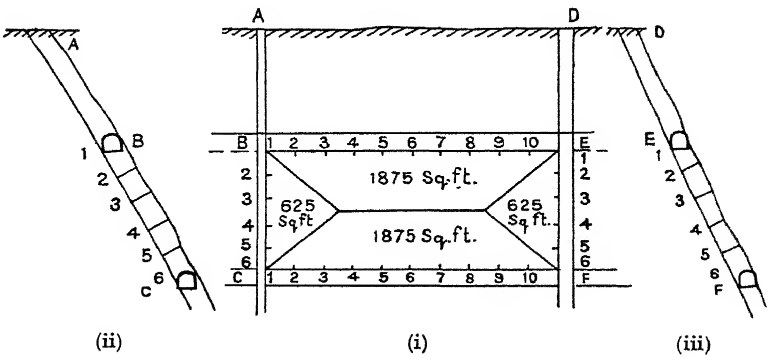


FIG. 17. Sampling of ore block underground.
(i) Longitudinal section, (ii) and (iii) end sections.

of a level, or in a winze or rise, and where the values are fairly regularly distributed, a number of small equally spaced chips may be broken from the face to form the sample.

To illustrate the method of calculating the average value of a developed underground block of ore, a copper deposit may be taken as an example. The samples are taken at fixed intervals along the levels and winzes (or rises) which surround each block (Fig. 17). It is necessary to weight the assay values for each side of the block. The results may be tabulated.

TABLE 4

Side BC.	Sample.	Width. T	Percent Cu. P	$T \times P$.
	1	10(5)	3·1	15·5*
	2	8	2·9	23·2
	3	9	3·2	28·8
	4	6	2·8	16·8
	5	5	3·0	15·0
	6	7(3½)	2·9	10·1*
		(36½)		109·4

* The two end samples Nos. 1 and 6 receive only half the weight of the intermediate assays as they represent only half the length between samples.

$$\text{Average assay} = \frac{109{\cdot}4}{36{\cdot}5} = 3{\cdot}0\%.$$

$$\text{Average thickness} = \frac{36{\cdot}5}{5} = 7{\cdot}3 \text{ feet.}$$

Repeat for each side :

Side EF.	Average	assay	= 2·5%.
	,,	thickness	= 6·4 feet.
Side BE.	,,	assay	= 2·9%.
	,,	thickness	= 6·9 feet.
Side CF.	,,	assay	= 2·8%.
	,,	thickness	= 6·7 feet.

TABLE 5

Side.		Volume of side.	Average assay.	$P \times V$.
BC	..	$625 \times 7{\cdot}3 = 4562{\cdot}5$	3·0	13687
EF	..	$625 \times 6{\cdot}4 = 4000$	2·5	10000
BE	..	$1875 \times 6{\cdot}9 = 12937$	2·9	37519
CF	..	$1875 \times 6{\cdot}7 = 12562{\cdot}5$	2·8	35175
		34062		96381

$$\text{Average assay} = \frac{96381}{34062} = 2{\cdot}8\% \text{ copper.}$$

$$\text{Average thickness} = \frac{34062}{5000} = 6{\cdot}8 \text{ feet.}$$

It might be contended that it would be more practical to determine the average for the whole block by merely obtaining the average of the values of the four sides weighted as to area. However, the method indicated here is actually just as simple, and is mathematically more correct.

Assay values are generally inserted on the mine plan according to the positions of the samples, thus forming an assay plan. The assay plan may indicate that part of a block is unpayable and allowance may be made for this in the calculations.

In mineral deposits of this type the distance between samples will depend on the extent of variation in values; the greater the variation the shorter the sample intervals. In some cases the values may be so erratically distributed that anything approaching a correct picture can be given only by the actual treatment of bulk samples of several hundred or even thousand tons.

In mica mining the values are commonly so erratic that, during development, only an idea can be formed as to whether the vein material left in the blocks will be payable or otherwise. A careful mica miner will record on his mica plans, however, the weight of crude mica per cubic foot of vein developed along each section of the levels and winzes. This may then give him some idea of the likely variation of the mica content in the blocks.

Example 7.—Sometimes it is necessary to find the average value of stacked mineral, or stock piles. In such cases the mineral

is drawn from several regularly spaced points on the dump, comparable to Fig. 12, and, if possible, material is taken from top to bottom of the dump at each point. If the mineral is finely crushed, a simple method of collecting the sample is to drive a 2-inch pipe through to the base of the dump and collect the material held in the pipe. In general, the material taken from the several points on the dump may be mixed as one sample. Should the dump be extensive, material from each point may be treated as a separate sample as in Table 2.

CHAPTER VII

ESTIMATION OF RESERVES

The methods for calculating the volume of a mineral deposit as well as its average composition were outlined in chapter VI. It is generally necessary to reduce the calculated volume into tons. For this purpose the average specific gravity of the ore or mineral aggregate may be required, but in mining it is more usual to express the specific gravity as the number of cubic feet of ore which equal one ton, generally known as the *foot-tonnage.*

The simplest and most accurate method of determining the foot-tonnage of a mineral aggregate in place is to weigh all the ore removed from one or more carefully measured openings. Thus, if 50 tons are excavated from an opening measuring $9 \times 10 \times 5$ feet, then the foot-tonnage is 9. The actual specific gravity in place, D, could also be calculated by dividing the weight of the ore by the weight of the same volume of water, thus—

$$D = \frac{50 \times 2240}{450 \times 62{\cdot}3} = 4{\cdot}00.$$

The specific gravity determined in this way is that of the total volume of rock, which includes not only the pore-spaces between minerals but also such voids as open joint planes and geodes. The more abundant the voids the lower will be the specific gravity. A certain amount of water is commonly contained in the voids of a mineral deposit. As water merely adds to the weight without affecting the volume of an ore, the specific gravity will increase up to the saturation point, according to the water content.

It is apparent that five distinct specific gravities could be determined:—

D = the specific gravity of the natural ore in place, with its normal water content still retained in the intergrain pores, joints and other cavities.

D_N = the specific gravity of a piece of the natural ore, just broken from its position, and with its normal water content still retained in the intergrain pores. This differs from D in that joint planes and other cavities are not included.

D_S = the specific gravity of the ore, pore-spaces saturated with water.

D_D = the specific gravity of the ore, dried.

D_M = the specific gravity of the total mineral constituents of the ore, without voids.

The only method by which D can be determined has been mentioned above. In some deposits it may not be possible to measure D, in which case D_N may be determined and a small allowance made for joint planes and similar openings, according to the apparent abundance of these in a particular deposit. To determine D_N, a series of representative samples of the ore should be collected, and the following procedure adopted for each :—

1. The sample is weighed—W_N.
2. The sample is dried for 12 hours at 100°C, or until the weight becomes constant, then weighed—W_D.
3. The sample is immersed in water for 24 hours, or until the weight becomes constant—W_S.
4. The specific gravity of the specimen saturated with water, D_S, is determined by means of a balance.
5. From D_S the volume of the specimen (V) is calculated—
$$V = \frac{W_S}{D_S}.$$
6. With V known, the weight of an equal volume of water is calculated, and
$$D_N = \frac{W_N}{\text{weight of equal volume of water}}.$$

The average of several specimens may be calculated. This may be readily converted into foot-tonnage (F)—

$$F = \frac{2240}{D_N \times 62{\cdot}3} = \frac{35{\cdot}95}{D_N}.$$

By substituting W_D for W_N above, D_D may be similarly calculated. The specific gravity of the total mineral constituents, D_M, can be determined by powdering the dried specimen and using a specific gravity bottle.

It is sometimes necessary to determine the porosity, P, of the ore. This can be calculated from the above:

$$D_M = \frac{D_D}{(1-P)}.$$

$$P = 1 - \frac{D_D}{D_M}.$$

Thus, if the specific gravity of the dried ore is 4·0, and that of the dried powdered ore is 5·0, then $P = 1 - \frac{4}{5} = \dot{0}{\cdot}2 = 20\%$.

Not infrequently minerals are sold on the dry basis, in which case D_D is of importance. So long as D_N and the moisture content M are known, D_D may be readily calculated:

$$D_D = D_N(1-M).$$

Thus, if the natural specific gravity is 4·0, and the moisture content is 20%—

$$D_D = 4(1-{\cdot}2) = 3{\cdot}2.$$

In hard massive ores in which open joint and other planes are practically absent, D_N may be accepted as equal to D, without any allowance being made. Where such openings are abundant in an ore-body it is necessary to add a few percent to the foot-tonnage calculated from D_N; the addition of 10% should be ample for the majority of ores. A list of the more common mineral deposits is given in Table 6, with the specific gravities of the pure minerals, and the foot-tonnage of the typical aggregates in which they occur.

The reserves of an ore-body are calculated by multiplying the volume (determined as in chapter VI) by the foot-tonnage.

In mining, the term *reserves* is generally applied only to such ore as systematic development has definitely proved to be present.

TABLE 6

Cubic feet per ton of mineral aggregate.

Mineral aggregate.	Specific gravity of pure mineral.	Cubic feet per ton of the usual aggregates. Foot-tonnage.
Asbestos rock	2·9–3·2	14–16
Barite	4·5	10–12
Bauxite	2·5–3·0	16–20
Bentonite	2·5 ±	20–25
Chromite	4·5–4·8	9–11
Clays	2·5 ±	20–25
Coal	1·4–1·45	25–27
Copper ore (chalcopyrite)	4·1–4·3	12–14
Diatomaceous earth	1·9–2·3	25–30
Felspar	2·6	15
Fluorite	3·0–3·25	13–15
Fullers earth	2·5 ±	20–25
Gold ore	..	13–15
Graphite	2·0–2·3	18–20
Gypsum	2·3	18–20
Iron ore	4·9–5·3	9–12
Kyanite	3·6–3·7	10–11
Lead ore (galena)	7·5	10–12
Limestone	2·7	15–16
Lithia (lepidolite)	2·8–2·9	15–16
Magnesite	2·8–3·0	13–16
Manganese ore	3·7–4·8	9–11
Mica vein	..	15·
Ochres	..	15–20
Phosphate (apatite)	3·2	12–14
Pyrite (massive)	4·8–5·1	8
Quartz	2·65	14–16
Sandstones	..	16–18
Sand and gravel (dry)	..	20–25
Slates	..	14–16
Sulphur	2·1	20–25
Titanium (ilmenite)	4·5–5·0	9–10
Vanadium (iron ore)	5·18	9–10

In an underground mine it will include such ore as is comprised in the blocks which have been developed on four sides. A mineral deposit generally extends beyond the boundaries of the carefully developed and sampled areas, and the terms *probable* or *apparent reserves* are used to denote that ore which it is reasonable to expect will prove to be present by later development; for example, if an ore-body has been fully developed down to 100 feet in depth, without any noticeable evidence of change, its persistence for another 50 feet is reasonable. In the prospecting stages of a mineral deposit *positive reserves* may be proved at the surface, or *minimum apparent reserves* may be calculated on reasonable assumptions and future increase in the positive reserves left to development during the life of the mine.

Not uncommonly the amount of reserves available may depend upon the market price, or the profits to be made from the various grades of ore available. The market price may be so low that it may be profitable to mine only ore above a certain grade, thus reducing the profitable reserves. On the other hand, increased efficiency in mining and treatment methods may permit a profit to be made from lower grade ore, thus bringing into reserves ore which had previously been omitted from calculations as unprofitable.

The calculated reserves may not be recovered 100% during actual mining. Due to various circumstances in mining there may be quite considerable losses—mineral left in the ground—and cases are not unknown in which only about 50% of the original reserves were removed; this applies more particularly to coal mining. In metal mining, 100% recovery of the original calculated reserves is quite normal, and 110% or even more is not unusual according to whether lower grade material has later been included.

CHAPTER VIII

MINING AND COSTS

Methods

The method to be adopted in excavating or mining any particular mineral is fundamentally determined by its mode of occurrence. Many minerals are restricted to the surface and, accordingly, are worked by open-cuts or quarries. Other minerals which are worked initially at the surface by open-cuts may be found to persist downwards to considerable depths, and may be then mined by underground methods. Underground mining is, in general, more expensive than quarrying, and a deposit which may be profitable to work at the surface may be unprofitable when it becomes necessary to follow the deposit underground. Normal peace-time prices are noted in this chapter.

Open-cut

Only a minimum of equipment may be necessary for the excavation of deposits at the surface. Certain minerals occur as superficial debris and require merely to be picked up and loaded into carts or trucks. In such a case costs amount to little more than the actual unskilled labour charges.

Other deposits, such as china clays, road metals and manganese minerals, may be worked from small open-cuts. These excavations may be in the hillsides, above the general level of the surrounding country, or they may be below the general level of the surrounding plain surface; in the latter case adequate pumping arrangements must be made to dispose of drainage water. Certain deposits may underlie surface debris, or be covered with valueless rock; this overburden must be removed before the mineral can be excavated, and occasionally the cost of moving this overburden may be such as to make the deposit unprofitable.

Small open-cuts may be worked entirely without power-driven machinery. If the material to be removed is soft, pick and

shovel may suffice; if blasting is necessary the requisite holes may be hand-drilled. Water may be removed by hand-pump from small open-cuts; a power-driven pump may be required where the seepage of water is excessive.

In India, the method of removal of mineral from small open-cuts below ground level is usually by means of baskets carried on the heads of coolies; convenient steps are generally cut in the sides of the excavation. Where the deposit is on a hillside and perhaps inaccessible to trucks or carts, a wooden or galvanised iron chute may be erected and the mineral thrown into the chute down which it slides into bins at the roadside below.

More extensive open-cuts, from which large tonnages may be removed, generally require a careful lay-out of quarry faces and tram tracks. Quarry faces should not exceed a certain height or steepness of slope as they may become dangerous or difficult to work; it may be necessary to have several faces and benches stepped one below the other, each bench with the requisite tram tracks on which the mineral is hauled in trucks from the quarry faces to the bins. Machine drills are commonly installed in such extensive quarries; air compressors may be steam or oil engine driven. Haulage may be by steam or oil-driven locomotives. In hill country where it is necessary to lower the mineral from the hill tops, aerial ropeways may be installed, although trucks on steep inclines are more commonly used. For actual excavation manual labour is still the rule in India, and thousands of coolies may be employed daily in large open-cuts; power-driven shovels have not yet come into extensive use.

Before despatch from the mine the mineral generally requires to be crushed to size. In the larger quarries the crushers are normally installed at the loading station, above the railway tracks.

Underground mining

Underground mining is generally necessary on those deposits which occur as definite beds, or as veins in the country-rock. They may dip at a shallow angle, as the seams in most of the coal mines in India, or they may dip steeply. For most minerals the particular

method of underground mining adopted may be determined by the steepness of the dip; in coal mining the method of working is governed primarily by the depth, thickness and dip of the seam.

For most bedded or vein minerals other than coal the technique of mining may be divided broadly into two distinct operations: developing and stoping. In the developing stage, shafts are sunk

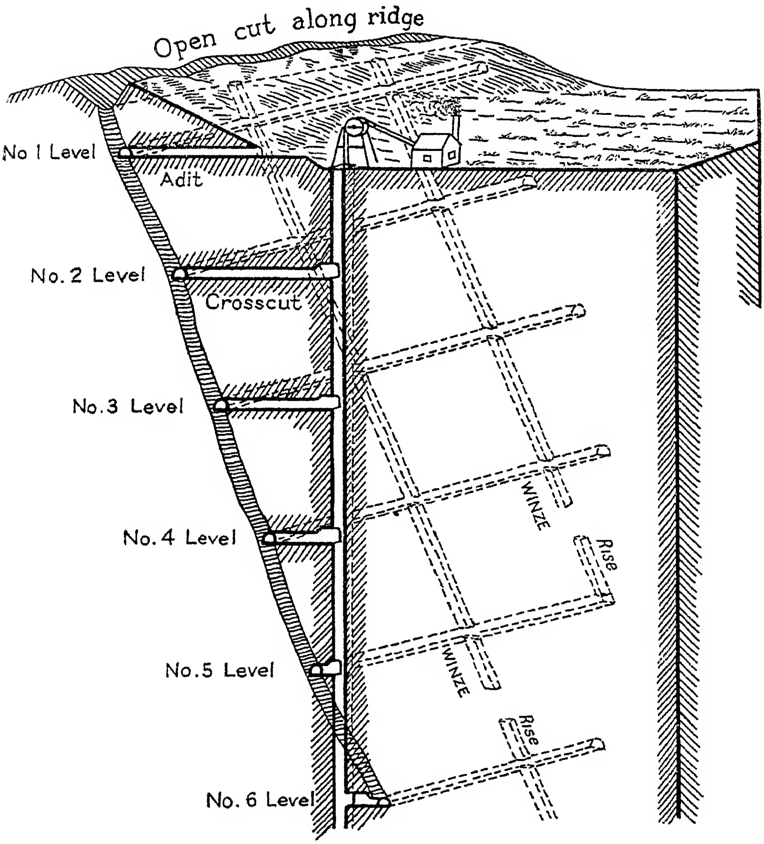


FIG. 18. Block section to illustrate adit, vertical shaft, crosscuts, levels, rises and winzes.

and crosscuts driven from the shaft to the deposit at regular intervals of depth; levels (or drives) are then driven from the crosscuts along the deposit and the levels connected by winzes and rises. In this way the deposit is made accessible and divided into blocks; accurate estimates may now be made of the reserves available.

With the establishment of workable reserves the blocks of payable ore between the upper levels are removed by *stoping*, but

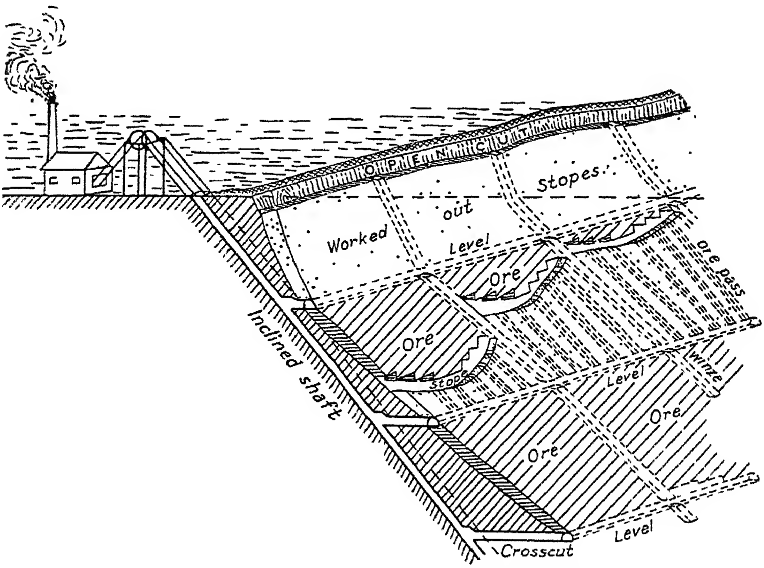


FIG. 19. Block section to illustrate inclined shaft, levels, stopes, and ore passes.

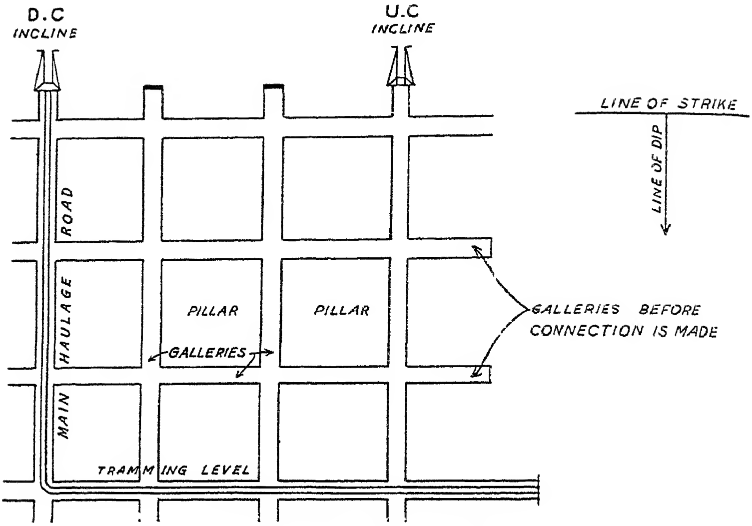
at the same time development is continued in depth, and laterally, if necessary, in order to maintain reserves. In mica mining, however, it is usual to develop the mica deposit to its ultimate limits, both laterally and vertically, before stoping is commenced. The actual methods of stoping adopted will depend upon the type and size of the deposit and the kind of country-rock

which forms the walls of the deposit. If the mineral vein or bed is narrow, and the country-rock shows no tendency to collapse, it may be possible to leave open the space from which the ore has been removed. Alternatively, it may be necessary to support the rock along the sides or walls of the deposit by means of timber, or to fill the space with waste as soon as the ore is removed. Such means of supporting the walls may be so expensive as to be prohibitive, but in certain cases it has been possible to dispense with them by introducing special methods of stoping which, however, are of too technical a character to describe here.

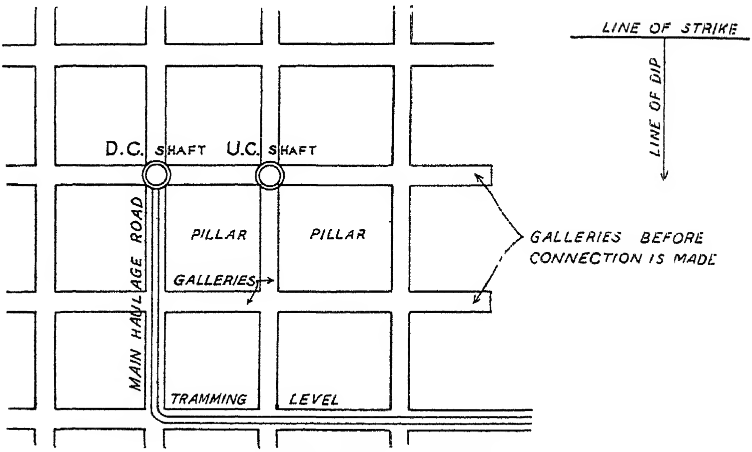
Machine drills are used in both developing and stoping, driven by compressed-air. After blasting down the ore in the stopes, the ore is dropped down chutes and loaded into trucks on the level below, then taken to the shaft and hauled to the surface. Here it is generally crushed to size before being transported to the treatment plant.

The above is a brief general outline of underground mining in vein, replacement or bedded deposits. The detailed methods vary widely for different types of deposit and many engineering difficulties, particularly in the case of the larger deposits, may require considerable technical skill.

In coal mining, most of the seams developed in India are gently-dipping (although there are important exceptions in Jharia and Assam), and the workings of any particular colliery may underlie many acres. Several seams may also be available within the one lease and precautions should be taken, by having the pillars vertically coincident, that the working of one seam does not weaken and cause the collapse of a seam above it. From the main inclines or haulage roads, driven down the dip of the seam, galleries are driven along the strike and off these other workings divide the whole area of coal into a regular system of workings with intervening square pillars. The sizes of the pillars and galleries vary according to the depth of the workings, and are provided for in the table embodied under Regulation 77, made under the Indian Mines Act, Table 7.



(*a*) Workings from inclines.



(*b*) Workings from shafts.

FIG. 20. Underground plans of coal mines.

(*D.C.* is the inlet down which fresh air passes to underground workings. *U.C.* is the outlet from which air passes after having traversed underground workings.)

TABLE 7

Depth of seam from surface.	Distances between centres of pillars when the average width of gallery is less than 10 ft.	less than 12 ft.	less than 14 ft.	less than 16 ft.
Less than 200 ft. ..	40	50	60	65
200–300 ft.	45	55	65	70
300–500 ft.	55	65	75	85
500–800 ft.	75	85	100	115
Over 800 ft.	95	115	130	150

Up to this stage between 25 and 40% of the coal will have been removed. The next stage is to remove the coal remaining in the pillars—this depillaring is advisedly commenced from the outer boundary of the mine, working backwards towards the shaft and, as the pillars are removed, the overlying strata are permitted to collapse. In some cases the space is packed by sand or other material thus supporting the roof; such packing is also an effective means of preventing spontaneous heating. Obviously, it is desirable to remove upper seams before depillaring the lower seams.

At some mines the coal is undercut by means of coal-cutting machines which make a cut 5 inches high and 6–8 feet wide at the base of the seam for the necessary distance along the seam. A few judicially placed holes are then drilled, explosive inserted, and the undercut coal blasted down. After loading into tubs the coal is hauled to the surface, where it is hand-picked and screened before despatch.

Mechanical equipment

Mechanical equipment in a mine is generally for the following purposes :—

(*a*) Pumping.
(*b*) Ventilation.
(*c*) Drilling.
(*d*) In coal mining—coal cutting (also for rock salt).
(*e*) Underground haulage.

(*f*) Shaft haulage.
(*g*) Haulage to treatment plant.
(*h*) Crushing.
(*i*) Workshops.

Pumping.—In small shallow workings a hand-pump may suffice for drainage purposes, where the volume of water is not excessive. As a rough guide, one man can pump 400–500 gallons per hour for a lift of 20 feet. In small underground mines, in which the volume of water is not great so that removal of the water may be intermittent, it may be baled out in buckets hauled up the shaft. For mines in which frequent or continuous pumping is necessary, power-driven centrifugal or reciprocating pumps are installed. These may be driven by steam or compressed air, or by oil engine, although electrical pumps may be employed on large mines. The efficiency varies according to the type of pump: steam pumps, up to 50%; compressed-air pumps, up to 25%; petrol-driven pumps, 25%; electrical pumps, up to 60%, depending on the lift and type of plant. The actual power required by the pump may be determined by the following formula:—

$$\text{b.h.p.} = \frac{C \times H}{3300} \times \frac{100}{E} = \frac{CH}{33E}$$

where C is the capacity in gallons per minute; H is the total head in feet against which the pump is working and includes the height to which the water is lifted plus an additional head lost through friction; E is the efficiency. Thus, for 100 gallons per minute, total head 200 feet and steam pump efficiency 25%, the power required will be—

$$\text{b.h.p.} = \frac{100 \times 200}{33 \times 25} = 24 \text{ h.p.}$$

For electrical pumps allowance must be made for efficiency of the motor. A vertical spindle 75 b.h.p. pump may deliver 1,000 gallons per minute against a vertical head of 150 feet. Air-lift pumps are occasionally used but are the least efficient. As may be readily

appreciated, pumping costs per ton of ore may vary enormously, from zero in dry mines to perhaps even 8 annas per ton.

Ventilation.—In deep mines, such as on the Kolar goldfields, mechanical ventilation is essential. In the majority of small mines in India the ventilation is natural and governed by the relative heights of the mine surface openings. Air drills help to improve ventilation. In certain workings, such as in long levels not connected with levels above, or in deep winzes, or in rises, fans or blowers may be necessary to force the air along canvas pipes up to the working face. For this type of work a small 8-inch fan with 8-inch pipe would require about 1 h.p.

Drilling.—Mechanical drills are invariably driven by compressed air. The necessary air-compressors are generally driven by steam or by oil engine. For a small mine a Diesel-driven two-stage compressor with a capacity of 120 cubic feet per minute (about 27 h.p., consuming about ·05 gallons of diesel oil per h.p. per hour) should suffice for two drills. Drilling speed will vary according to the rock, but 100 feet per 8-hour shift is quite common in white quartz. In coal, where drilling is done mechanically, 55 feet per hour, that is 10 holes of 5 feet 6 inches each, is common, but drilling speeds vary enormously. The length of each hole may vary according to the work; in mica mining short holes of only one or two feet are usual in stoping, where only 3 sticks of 7/8-inch gelignite are used, but in copper mining 6-foot holes are often the practice.

Coal cutting.—Chain coal cutters making a cut 5–7 inches high and 8 feet in width require about 30 h.p. An average length of perhaps 100 feet of coal can be undercut per shift. Cost of coal cutting is approximately 2-2½ annas per square foot.

Underground haulage.—In India haulage underground between the working face or chute and the shaft is generally by hand-pushed tubs. Traction by storage-battery locomotives is normal practice in metal mines in most countries but not in India. In coal mines, or on large surface collieries, the tubs are hauled by mechanically driven wire ropes up inclines; however, in at least one Indian colliery electric locomotive traction is used underground. In other mines the mineral may be hauled in buckets or skips up winzes

or steep inclines, the rope being driven by compressed-air hoists or winding engines. Obviously, haulage costs in individual mines may vary very widely indeed; for haulage along levels up to 2 annas per ton mile is a reasonable cost.

Shaft haulage.—In a small prospecting shaft the mineral may be hoisted by means of bucket and hand windlass. For a deeper shaft, with mechanical hoist, a headframe is erected over the shaft to support the pulley or winding wheel over which the hoist rope passes. On small mines, the headframe may be constructed of timber, but for shafts of any permanence steel headframes are preferable. In India winding engines are generally steam-driven. Wire ropes are tested periodically. The mineral is hoisted by buckets in small mines and by skips or cages in larger mines. Costs of shaft haulage vary according to depth, speed of hoisting, power requirements, etc.

Haulage to treatment plant.—Haulage from the mine to the treatment plant may be by locomotive, aerial ropeway, or by motor truck. Costs range considerably, but with adequate output they should be less than 2 annas per ton mile for locomotive traction and 2 annas per ton mile by aerial ropeway, whilst 2-3 annas per ton mile by motor truck would be representative under reasonable conditions.

Crushing.—The principal primary ore-breakers used today are gyratory crushers and jaw crushers for coarse crushing, and rolls and disc crushers for intermediate crushing; gravity stamps are still in use on some gold ores. Each type has its particular advantages for various kinds of minerals. Costs vary according to the toughness of the mineral and the size to which it has to be crushed.

Workshops.—These include blacksmiths, tool-sharpening shop, and fitting and turning shop for general repairs and construction. Large properties may have their own pattern-making shops and foundries for making their own castings.

Maintenance.—The care and upkeep of equipment on a mine must receive close attention. Adequate stocks of spare parts should be kept in order to avoid loss of time from a breakdown.

Although the cost of careful maintenance may appear somewhat heavy it will certainly help to extend the life of equipment and thus reduce mining costs in the long run. Many small mine owners at present hesitate to employ skilled machine attendants, but it would certainly pay them to do so.

Explosives

There are several kinds of explosives marketed for use on mines. On the coalfields black powder is generally used, but in hard rock mining high explosives of the blasting gelatine type are preferable. The amount of explosives required per ton of mineral produced will vary widely according to the toughness of the rock, the method of mining, and the experience of the miner. As explosives are costly it is desirable to reduce the amounts required to a minimum and judicious spacing of the drill-holes is of the most importance.

Power

On smaller mines power for compressors, etc. may be generated by small petrol or Diesel oil engines. Vertical boilers capable of providing 8–30 h.p. are commonly used on small mines as they are easy to handle and are more or less fool-proof. Larger mines may require a carefully designed power plant, with capacity perhaps of over 4,000 kw, generating current not only for all the underground work, workshops, surface haulage, and lighting, but also for a complicated chain of ore-treatment. A large iron and steel centre, such as Jamshedpur, may require over 40,000 kw. Under such conditions the generation of power may become one of the principal departments of a mining organisation.

General costs

It will be readily appreciated that mining costs vary considerably and depend mainly upon the type, size, and grade of the mineral deposit, method of working, cost of labour, supplies, power, and accessibility.

Mining costs are distributed over several items: labour, supervision and administration, power, explosives, timber and other supplies, transport, depreciation of plant, surveying, lighting, repairs, water supply, medical supervision, and sanitation. As a rule, it may be stated that labour is responsible for more than half the total mining cost. Most of the other items of cost, per ton of mineral, will depend to some extent upon whether the production tonnage is large or small. In difficult hill country, transport to railhead may exceed the total of other costs. In malarious areas medical costs may be high.

As labour is the dominant item, it is apparent that efficiency of the labour force available must receive constant attention. Highly skilled labour is not normally essential in surface mines, although costs of drilling for blasting will be less if men skilled at hand-drilling or in the use of machine-drills are available. A greater proportion of skilled men is advisable in underground mines, particularly for machine-drilling which may be the most costly item in hard rock.

Unskilled labour is generally obtainable in India at rates ranging from 4 to 8 annas per day, but in rather inaccessible places, such as on the Frontier, even 10 to 12 annas per day may be paid. Skilled machine-men may be paid up to Re1-4-0 per day. A common practice is to pay on piece rates, at so much per ton excavated, or according to the footage drilled in the case of machine-men. In open-cuts, excavation work is commonly undertaken by contractors who employ their own labour and are paid at an agreed rate per 1,000 cubic feet.

The tonnage which can be excavated per day, per miner, will naturally depend upon the hardness of the ore, its specific gravity, and its ease of handling. In open workings, for iron ore the production per miner may be only one ton per day, whereas for an easily worked mineral, such as sulphur, up to 3 tons may be possible. Calculating from the total labour employed for all kinds of work during the year on the Central Provinces manganese mines, the average daily production comes to only 0·1 tons per head. In underground mining, where mechanical equipment is so essential to

reduce costs, the daily tonnages handled per head may be rather higher than in open workings and over 5 tons is common where a minimum of handling is required.

One of the most expensive items in mining is drilling. Where hand-drilling is used, the footage in such a rock as white quartz may be only 3 feet per shift, but with machine-drills in the same rock over 100 feet per shift would be quite common. However, depreciation of machines, cost of sharpening drill steel and wear on the latter, air-compressors, etc., all add to the cost, and in an iron ore mine, for example, the actual cost of machine-drilling may be about half the cost of hand-drilling. In underground mining, drilling costs for development work—driving levels, etc.—are much greater than for stoping; in stoping, only sufficient holes are drilled to break down the ore and not uncommonly much of the ore may be brought down with crowbars. Hence, average drilling costs per ton of ore vary considerably from mine to mine—perhaps a good average in quartz would be 4–8 annas per ton; extreme costs for machine-drilling would be Re1 per ton, and for hand-drilling Rs2.

Explosives may constitute a quite considerable item of cost where the ore is hard and massive, rising to 6 annas or even 8 annas per ton under some circumstances.

Timber is little used in most open-cut mines but in some underground mines it may be a most important item of cost, equal almost to the labour charges.

Power costs for haulage, compressed-air, crushing, workshops, and perhaps lighting, will depend on fuel costs and on the outlay for power plant. Fuel costs vary to some extent according to the relative accessibility of the property. For individual mines generating their own power from purchased coal, power costs may be as low as ·25–·5 annas per kilowatt, increasing to over 1 anna per kilowatt according to the price of coal or fuel oil, the size of the plant, and its efficiency.

Even on surface mines, haulage may add considerably to costs. It may be necessary to utilise motor transport from isolated deposits to bring the ore to the despatch centre, and, with very bad roads, surface haulage may add 4–6 annas per ton to the costs *ex*-mine.

In any statement of mining costs the various items may be grouped as follows:—

1. Prospecting and initial development.
2. Development chargeable to capital.
3. Development chargeable to revenue.
4. Stoping.
5. Depreciation of mining plant.
6. General expenses.

If the mineral is treated by the same company, the following costs should also appear:—

7. Transportation to treatment plant.
8. Treatment costs.
9. Depreciation of treatment plant.

For open-cut mines the total mining costs in India range widely from approximately Re1 per ton to Rs8 per ton, depending upon the ease with which the mineral is extracted; costs exceeding Rs4-8-0 would be due to a combination of very unfavourable circumstances, generally resulting from inaccessibility. For underground mines perhaps the lowest costs are to be found in the coal-fields where the minimum costs with reasonably efficient methods of working are Rs2-8-0 to Rs3 per ton; for hard ore mines working efficiently the costs may be Rs6 to Rs7 per ton, but in small mines using hand-drilling and requiring a considerable amount of development to open up small deposits, costs as high as Rs15 per ton of mineral at the mine head are not uncommon.

Mining costs of certain minerals

Asbestos.—Prospecting costs for a mineral of this nature, which is generally very haphazardly distributed, are likely to be high. In both open-cut and underground workings on any particular deposit the mining costs per ton of asbestos will depend mainly on whether the mineral is abundantly or sparsely distributed in the rock excavated. Many asbestos deposits are amongst the most speculative undertakings. In South India, underground mining costs have been quoted at about Rs14 per ton of rock, or

Rs56 per ton of asbestos produced, but these figures would suggest much scope for improvement in mining methods. Milling costs have been quoted at Rs20 per ton, carting to station Rs10, total Rs86 per ton.

Barites.—Where it can be mined by open-cut the cost of extraction of barite should not be in excess of Rs2 per ton, costs on wider deposits being less than on narrow veins. If the workings are extended underground the costs may increase to Rs7-8-0 per ton depending on the type of country-rock and the output of mineral; under favourable circumstances reduction of costs to Rs5 per ton should be possible. Hand-sorting, crushing and grinding may add Rs3 or more per ton. Where treatment is necessary to increase the grade, costs would be further enhanced. Bagging, transport, and sale charges have also to be added and, for a low-priced material of this nature, these must be low.

Bauxite.—This mineral is excavated by open-cut and costs are largely determined by thickness of overburden. The ore is soft and generally occasions little difficulty in removal. Mining costs should normally be less than Rs3 per ton. Most of the deposits are at some distance from the railway and transport costs are generally high.

Bentonite.—The cost of mining bentonite clays by open-cut should be between Re1 and Rs2 per ton.

Beryllium.—The cost of production of beryl from pegmatites, cobbed to over 12% BeO, is generally about Rs60 per ton, but may be as much as Rs100.

Chromite.—Chromite veins in India are generally relatively thin and impersistent; surface workings may be continued in depth as underground workings. Although surface chromite may be mined for up to Rs5 per ton (even higher figures have been quoted), costs of underground mining on these small veins are likely to be as high as Rs10 per ton, and perhaps in some cases even Rs15. Costs exceeding even Rs40 per ton are reported in Singhbhum. A certain amount of hand-sorting is done at the mines, and poorer quality material is occasionally concentrated in a rough fashion by winnowing.

Clays.—Fireclays and stoneware clays are mined both by opencut and by underground workings. Costs are between Re1 and Rs2 per ton; prices paid to contractors *f.o.r.* nearest railway may be as low as Re1/2½ per ton, but efficient working can scarcely be expected in such cases. There is little doubt that as the Gondwana clays are removed at the surface and deeper workings become necessary, costs will increase. Not uncommonly, transport costs to firebrick works exceed mining costs.

China clays may be mined for Re1 to Rs3 per ton, depending on the overburden and the degree of selection required to avoid stained material. Washing costs are higher than mining costs; only one ton of refined clay may be obtained from 5 to 8 tons of crude. A crude clay, mined at say Rs2 per ton, may result in a refined clay which has cost Rs15 per ton.

Coal.—The average total cost at which coal can be normally produced in Bengal and Bihar is between Rs2-8-0 and Rs3 per ton. At certain quarries on coal outcrops the costs may be below Rs2. In the more distant fields, Central Provinces, Assam, and Northern India, costs are appreciably higher. At Palana, in Jodhpur, from a 6–30 foot seam of lignite at a depth of 250 feet the production is about 170 tons per day, and the actual mining cost is only Rs1-2-0 to Rs1-4-0 per ton, and including overhead charges Rs1-13-0.

Copper.—The total cost of production of a ton of copper is divided mainly between mining, milling, and smelting. The costs will vary according to the type, size, and grade of the ore-body, method of mining, cost of labour, accessibility, efficiency in milling, smelting, etc.

For an average ore-body, producing between 500 and 1,000 tons of ore per day, the ore grading between 2% and 3% copper, the costs may be roughly divided as follows: one-half in mining, one-quarter in milling, and one-quarter in smelting and other charges. If the ore-body is narrow, with much barren ground between the ore-shoots, or should the ore-body be small and worked with a minimum of plant, the ore being sold to a mill or smelter, the mining costs may be as high as 75% of the total. In India, for the type of ore-

body quoted above the total mining costs would be between Rs7 and Rs10 per ton of ore.

It is apparent that, although constantly increasing efficiency in milling and smelting is always desirable, reduction of mining costs must receive the closest attention. A reduction of one anna in the cost per ton of mining a 2% ore will mean a reduction of more than Rs3-2-0 in the cost per ton of the refined metal. A mine may be producing 1,000 tons of ore per day, averaging say 2% copper; this will be concentrated in the mill to less than 80 tons of concentrates, which will be converted by the smelter to less than 20 tons of copper. During both milling and smelting there will be some loss of copper: a 98% recovery of copper as sulphide in milling, and a 95% recovery of the copper smelted from the concentrates is attained at the most efficient plants. It is apparent that the maximum percentage of extraction becomes of great importance in these final processes. Labour costs become of decreasing importance in milling and smelting compared with other charges such as power and plant. In milling, grinding costs per ton of ore are perhaps the most important and require the closest attention; they are affected little by the grade of the ore. Total grinding and concentrating costs will vary widely for different conditions but Re1 per ton of ore would be exceptionally good. Obviously, in terms of copper content, the milling costs will increase conversely with the ore grade. In smelting, reduction of fuel costs is perhaps the main consideration. It is doubtful whether copper could be produced in India for less than Rs550 per ton, inclusive of all charges.

Feldspar.—Cost of mining feldspar in open workings would be about the same as for any other small veins, Rs2 per ton. Sorting and hand-cobbing costs may add Rs5 per ton. Total costs of feldspar as marketed are likely to be up to Rs7 or Rs8 per ton.

Fluorite.—In open-cuts, cost of mining fluorite may be approximately Rs2 per ton, rising to perhaps Rs8 for underground mining. Treatment costs will vary according to the methods necessary and the tonnage, and, with amortisation of plant where

flotation is used, may add up to Rs15 to Rs20 per ton of concentrates for a small plant.

Gold.—In mining gold-bearing veins, costs are comparable to those for copper veins. For small veins, a rough estimate of Rs10 per ton may be taken. Crushing and grinding costs, or stamping, may add as much as Rs2 per ton, and total milling costs, including amalgamation and cyanide treatment, would be about Rs5. Total costs would therefore be about Rs15, equal to 3 dwts on present gold prices.

Graphite.—In India, graphite is mined by open-cut and costs for crude graphite may be up to about Rs3 to Rs4 per ton; costs as low as 8 annas per ton have been recorded but refer to labour charges only. Concentration costs vary according to the efficiency of the treatment, for there may be considerable losses in washing. At one mine, with crude mineral ranging between 18% and 30% graphite and washing to only 35%, the washing costs were Rs30 to Rs40 per ton of concentrates—inefficient treatment is obvious in this case.

Gypsum.—Where solid gypsum-rock is exposed at the surface without overburden, mining costs may be Re1 to Rs1-8-0 per ton, but where a considerable amount of surface soil and debris has to be turned over the costs may be considerably greater and up to Rs6 to Rs7 per ton. Crushing and grinding costs may add about Re1 to Rs2 per ton.

Iron ore.—Costs of mining iron ore vary according to the type of ore mined and the relative accessibility. Debris may be mined very cheaply indeed, in some cases for little more than 8 annas per ton. Hard-bedded ore generally has to be mined under close technical supervision and costs may total Rs1-8-0 to Rs2-4-0 at the railhead; in hill country, where transport from the quarries to the ore bins may be lengthy, and supplies, crushing, and other costs may be considerable, total costs may be as high as Rs3.

Kyanite.—Most of the kyanite mined in India is merely surface debris, boulders taken from the surface. If the boulders are thickly distributed the cost of mining is only a few annas per ton, increasing where the boulders are more sparsely scattered.

Boulders which are too large to handle must be broken to reasonable size; as the rock is extremely tough, labour for breaking will raise considerably the mining costs, which may be as high as Rs3-8-0 per ton.

Limestone:—The majority of limestone deposits suitable for quarrying are comparatively large and the daily tonnage mined is considerable, so that, per ton of mineral, the overhead costs are relatively low. Limestone cropping out at the surface may be mined in some circumstances for Re1 to Rs1-8-0 per ton, but if a thick overburden has to be removed the costs may exceed Rs2-8-0. No sorting has to be done and the limestone may be sent direct from quarry face to crusher.

Magnesite.—Workings on magnesite deposits are invariably open-cut and, provided that overburden is not thick, costs should not exceed Rs3 to Rs4 per ton.

Manganese.—In India almost the whole of the manganese ore is mined by open-cut methods. The open-cuts vary from shallow surface workings on the superficial or lateritoid ores, to the removal of the upper part of ridges, as at Dongri Buzurg in the Central Provinces, or to deep quarries as in the original Balaghat workings. Underground methods have now been adopted to work the deeper continuation of the Bharweli deposit at Balaghat. Where necessary, drilling is usually done by hand, and the method of hand mining requires a large labour force. As in iron ore mining, women are employed to a considerable extent for carrying the ore from the quarry face to the trucks and for sorting into grades.

The average mining costs in the Central Provinces, including labour, tools, plant, and administration, total about Rs4-4-0 per ton. Transport to railhead averages nearly 3 annas. Freight to Vizagapatam may be about Rs8 per ton and to Calcutta about Rs10-8-0. Port charges may be Rs1-7-0 at Vizagapatam and about Rs1-13-0 at Calcutta, to which may be added agent's commission and other expenses, amounting to 3–5 annas. Hence, the total cost of delivering manganese from the Central Provinces *f.o.b.* Vizagapatam or Calcutta may be Rs14 to Rs17.

In other parts of India, as in Singhbhum, costs may be lower, as many of the deposits are right at the surface and actual mining costs may be less than Rs2 in some cases, particularly where little or no sorting is necessary. Haulage by motor truck may add considerably to this figure.

Mica.—The amount of mica which occurs in a vein varies considerably but in the Bihar mica belt, in those pegmatite veins which produce mica, about 1 maund of crude mica is obtained from 8 cubic feet of vein material. Of dressed block mica this represents 1–1·5% of vein material. The amount of block mica obtained per annum from each mine may range from a few hundredweight at small mines to more than one thousand hundredweight at large mines in process of stoping. In the Kodarma Reserved Forest, where the leases are divided into 40 acre squares, the annual average production per acre of leased ground in normal years is about 2 cwts of dressed block mica. Only a certain proportion of the leased squares are actually working throughout any one year, however.

Most of the mica is obtained from underground workings, although some is still obtained from surface workings. In Bihar the mining cost is between Rs5 and Rs10 per maund of crude mica. Costs in Madras are about the same but in Rajputana, where the veins are mined by surface cuttings, costs may be only Rs3-8-0 per maund of crude mica. The crude mica is dressed to block mica in Bihar at an average total cost of about Rs50 per maund of block.

Mineral pigments.—In India ochres are generally mined by open-cut but there have been cases in which ochres have been mined below laterite by underground methods. Although the mineral is soft and easily excavated, a certain amount of selection has to be made and much overburden may need to be removed, so that costs may range from Rs2 to Rs6 per ton; if the crude ochre requires washing the total costs may be further increased.

Monazite.—As monazite is obtained as a by-product during concentration of ilmenite sands, costs are not ascertainable.

Petroleum.—Oil-bearing strata are tapped by means of bore-holes, which may extend down to as much as ten or even fifteen thousand feet in exceptional cases. The cost of drilling any

particular well may be only a small part of the total production cost. Once an oil occurrence is located and tapped, the rate of extraction of the oil will depend to some extent on the attitude of the particular company. A small company may desire the maximum immediate output in order to obtain a quick return of capital expenditure and the oil pool may be soon exhausted. A large company, which has also extensive interests elsewhere, will exploit the oil pool with the object of obtaining the maximum ultimate recovery and the annual yield will be maintained at a steady rate over many years. Increasingly skilled technique is used to prolong the life of an oil pool. Costs of individual wells vary enormously and may reach several lakhs of rupees. Several companies or well owners may combine to develop an oil-bearing structure as a unit, thus avoiding the losses necessarily involved in competitive development.

Phosphates.—No details of cost are available for the phosphate nodules collected from the surface in Trichinopoly but the material is generally sold for about Rs10 per ton. Apatite veins may be mined for about Rs3 to Rs5 per ton, but this is increased by sorting and crushing.

Salt.—In the Salt Range, Punjab, rock salt is mined underground. Pillars are left to support the roof in a manner similar to those used in coal mining. Machine cutters are used for undercutting the salt. The average mining costs are between about 2 annas 4 pies and 3 annas 4 pies per maund; of this, labour costs are 1 anna 2 pies to 1 anna 4 pies per maund; costs of machine cutting are generally between about 2 annas 8 pies and 5 annas 8 pies per square foot.

Salt evaporated from inland lake brines, such as Sambhar Lake, may cost up to about 3 annas per maund ready for sale; from sub-soil brines the cost may be about 3 to 4 annas per maund; from seawater the cost is 2 to 4 annas per maund.

Silica, sand, and gravel.—Quartzite for the manufacture of silica bricks is quarried at a cost of up to about Rs3 per ton. The rock is generally crushed at the firebrick works. Fine friable sandstones for glass manufacture are softer and more easily quarried, so that costs are lower, Rs1-8-0 to Rs2. Quartzite and quartz used

for ballast cost about the same. Sand and gravel may be quarried for between 8 annas and Rs2 per ton according to the degree of selection and screening necessary.

Slate.—In India slates are quarried but underground methods are used in some countries. Costs are difficult to gauge as they vary widely according to the size of the finished slate, but actual mining costs of the total quarried material should not exceed Rs2.

Strontium.—The Madras deposits of strontium have not yet been actively exploited. Costs would be difficult to estimate, but should be below Rs8 per ton.

Sulphur.—Although deposits of pyrite are known in India, sulphuric acid manufacturers prefer to use sulphur rather than pyrite. If mined efficiently, costs should be between Rs8 and Rs10 per ton of pyrite at the mine, although they may be as high as Rs15 per ton in the early stages of development.

The only sulphur mine worked in India is at Koh-i-Sultan, Baluchistan, where the costs at the mine depots are Rs8 to Rs10 per ton; this refers to open workings in an area which is relatively inaccessible, and costs of supplies, water, etc., are abnormally high.

Talc (steatite).—Steatite is mined invariably by open-cut in India. Costs vary according to the amount of selection necessary both of quality and size of the blocks excavated. Where little or no selection is necessary, costs may be as low as Rs2 to Rs3 per ton, but where great care has to be exercised in removing large flawless blocks costs may be over Rs30 per ton.

Titanium.—Figures are not available of costs of excavating and concentrating the ilmenite sands of Travancore. As the sands are at, or close to, the surface, and as crushing is unnecessary and the sands merely require to be passed through simple classifiers and over tables, costs should not exceed Rs4 to Rs5 per ton of concentrates.

Tungsten.—At Degana, Jodhpur State, the *in situ* ore is procured from open-cut workings, but the greater part of the ore is obtained from the eluvial deposits by means of quarries and shallow underground galleries—pillars being left to support the roof. The yields are generally about 3 lbs per cubic yard. Labour is cheap. The working costs are approximately Rs700 per ton of concentrates.

CHAPTER IX

TREATMENT OF MINERALS

The treatment through which minerals may pass between the mine and the point of consumption or the final manufactured article may be highly technical or varied. In this chapter it is intended to give merely a brief outline of the processes to which minerals, likely to be of interest to investors in India, may need to undergo before they can be marketed. More detailed information is, of course, available in the many technical publications available on the various industries.

Abrasives and grinding materials.—Corundum and garnet may be sold direct, in the crude form. Before manufacture they may be crushed and sized. Such abrasives and polishing media as sand, feldspar, limestone, talc, etc., which are used in the powder form, are ground in mills and then sized usually by screening. Pebbles, such as flint or chert, which are required for ball mills may need to be graded as to size. Grindstones or millstones and sharpening hones, such as fine sandstone, quartzite, granite, or trap, need to be shaped to size. Certain stones used for pulping are seasoned by soaking them in water and allowing this to evaporate over a period of many months, the stone hardening in the process.

Artificial abrasives have not been manufactured in India as yet but materials are available for the manufacture of silicon carbide (carborundum) and fused alumina (alundum). Cheap electric power for the furnaces can be obtained.

Asbestos.—On removal from the mine the longer fibre asbestos is freed from associated rock material and then graded by hand according to the length of fibre. The remaining rock is crushed and beaten and the liberated fibres drawn off by an exhaust fan. The better quality fibres may be spun and then woven into cloth in the same way as cotton or any other fibre.

In India, asbestos is made up into asbestos board and asbestos sheet. It is also used as packing and lagging for engineering purposes.

Barite.—Apart from hand-picking to remove associated rock material, the barite from many deposits merely requires to be finely ground and sized to 200–300 mesh before being used in paint or as a filler in other industries. Concentration to remove other minerals, where necessary, is generally done on shaking tables, and bleaching with dilute sulphuric acid may be required in some cases.

Bauxite.—For the purification of kerosene, or for the manufacture of high quality refractory bricks and of alumina cement—its simplest uses—bauxite requires to be ground to size. Calcining is also necessary before manufacturing into refractory bricks or abrasives. For the manufacture of chemical products, alumina, and aluminium, bauxite passes through a series of complex technical processes. In the production of aluminium, the bauxite is first purified by chemical means to aluminium hydroxide which is calcined to alumina, and the latter reduced electrolytically to aluminium in a bath containing molten cryolite.

Bentonite.—Clays of the bentonite type merely require to be dried, and in some cases ground to 200 mesh.

Beryl.—After freeing the mineral from quartz or feldspar by hand-cobbing, beryl is exported in lump form. Its treatment for the extraction of beryllium is a complex metallurgical process.

Chromite.—The chromite ore as mined is graded according to chemical composition. For the manufacture of chromite refractory bricks the mineral is crushed to size and bonded with such material as magnesite or fireclay; it commonly receives a prior heat-treatment to stabilise the chromite. Ferrochrome, used in such alloys as stainless steels, is smelted from the mineral in electric furnaces. Chromite is also the basis of chromates prepared in chemical industries.

Clays.—Fireclay is sent in the raw condition to the firebrick factories, and stored in an exposed position for as long a period as possible to permit the clay to be weathered, the lumps disintegrating. The clay is then ground under rollers, and screened to eliminate

coarse particles. After mixing with water the clay is thoroughly worked up or 'pugged' in machines, and is then ready for moulding into bricks or other articles. After controlled drying the moulded articles are burnt in kilns at temperatures between 1200°C and 1400°C.

China clays invariably require the removal of impurities after excavation from the mine. The principal impurity is fine quartz which makes the clay gritty, and this is removed by washing. The method of refining generally adopted in India is very crude: the clay is washed in a tank with water and the thin liquid run off through settling tanks, the grit being left behind; the final clay solution is sun-dried. The method is wasteful and depends upon the vagaries of the weather. Mechanical methods of refining in elutriators, with mechanical filtering and drying, have been successful; they are more efficient and yield a better product, although they are more expensive. The proportion of refined clay to material excavated from the mine averages about 20% but may be as low as 5%. Most of the Indian china clays are used in the textile and paper industries as fillers and in pottery work.

Coal.—Over 90% of the coal mined in India is used directly as fuel. Apart from screening to remove slack, the coal is despatched straight from the collieries; improvement of quality of coal by various beneficiation methods, such as washing, has not become a widely accepted practice in India as yet. Over two million tons of coal are required annually for the manufacture of hard coke, more than 75% of which is used in the iron and steel industry. In the manufacture of hard coke the coal is carbonised in ovens and certain by-products, such as coal gas, tar, naphthalene, ammonia, and benzole, are recovered. Less than one million tons of soft coke are manufactured each year in India from inferior quality coals; the coal is merely carbonised in the open at a low temperature and the products sold for domestic purposes—in this process the wastage of volatile products is enormous.

Copper.—As most sulphide copper ores contain under 4% copper it is necessary to concentrate them, thus eliminating much waste material before smelting. The crushed ore from the mine is

ground to very fine size; the most prevalent method of concentrating the metallic minerals is by flotation. In this process certain oils and other reagents are added to the water carrying the fine ore in suspension, and the solution is then aerated in the flotation 'cells' by one of several methods; the metallic minerals collect as a film on the surface of the bubbles and are carried upward to the top of the cells whilst the valueless minerals are depressed to the bottom of the cells and run off as 'tailings'. Such a process may be selective and designed to separate in turn two or more valuable minerals. The concentrates are filtered and dried and are then ready for the smelter.

Modern practice in smelting copper sulphides is divisible into three stages: separation of the sulphide from the rest of the ore by simple smelting, removal of the sulphur from the copper sulphide by oxidation, refinement of the copper. In some plants (*e.g.* Indian Copper Corporation) a portion of the sulphide concentrate is roasted to oxide before smelting. The concentrates are then charged to a reverberatory furnace, copper and some iron sulphides with any precious metals present collect in the bottom of the furnace as 'matte', whilst silica and other impurities form a slag above the matte. The matte is tapped off and poured into converters in which air is blown through the molten sulphide, thus driving off the sulphur as SO_2 whilst iron forms an oxide slag. The resulting metallic copper as poured from the converter is known as 'blister copper' and may contain 2–5% of impurities.

The blister copper may be refined either by a furnace method or electrolytically. In the furnace method the blister copper is remelted in a reverberatory furnace, impurities are oxidised and converted into slag, and the refined copper, when poured into ingot form, assays over 99·2% although certain ores may yield a furnace refined copper assaying over 99·8%. Most of the world's copper is now refined electrolytically. In this method the blister copper is cast into the form of plates which are suspended as anodes in the electrolytic bath, and the copper is then precipitated on the cathodes. Valuable constituents, such as gold, silver, platinum,

etc., if present, collect with other impurities in the sludge at the bottom of the bath and are recovered later.

In some plants, where the ore is partially roasted, the manufacture of sulphuric acid or the collection of sulphur from the roaster gases may be a by-product industry. In many ores the yield of precious metals is a valuable addition to the company's earnings and not uncommonly other by-products, such as nickel, arsenic, selenium, etc., are collected. The Indian Copper Corporation uses the furnace method of refining because (*a*) the ore contains no precious metals, (*b*) almost the entire production is converted into brass for which electrolytic copper is not necessary, and (*c*) additional costs in electrolytic refining would not be repaid by the additional price of electrolytic copper.

Feldspar.—The raw material for ceramic ware and glass must be free from impurities such as iron oxide which would either colour the finished product or occasion difficulties in manufacture. Hence feldspar should be very carefully cobbed and hand-picked to remove such minerals as mica, quartz, tourmaline, etc. It is not essential to remove all the quartz, but this should be reduced to a minimum. Before mixing with the ceramic or glass batch thé feldspar must be finely ground, generally in pebble mills.

Fluorite.—The majority of fluorite deposits contain impurities; some, such as calcite, are not particularly harmful in steel smelting, but sulphides are harmful if present, and quartz reduces the value of the fluorite as it requires fluxing. Deposits may contain 25% and over of fluorite and need to be concentrated to over 80% for metallurgical purposes and over 98% for chemical purposes. To remove impurities the fluorite may be hand-picked, crushed to size and screened, and finer material washed by one of several methods. Flotation has been successfully introduced in many plants in America; this process undoubtedly gives the most successful results, particularly for chemical purposes. A middling product is used in steel manufacture after sintering.

Fullers earth.—The clay is dried and may then be passed through mills to be crushed to size.

Gold.—Alluvial gold deposits worked with dredges on a large scale may be payable even if only containing a few grains per cubic yard. Gold veins are payable at values ranging from 4 dwts and over; the latter is about the lowest profitable limit in India.

Treatment of gold ores from veins in different parts of the world varies widely but modern treatment tends to the following general procedure. The ore is crushed, then ground either in stamp batteries or ball or tube mills. The stream of fine ore and water is passed over a sloping table covered with corduroy, the fine gold and sulphides being caught in the space between the corduroy ribs. About 3½ square feet of corduroy are required per ton of ore per 24 hours, or about 0·20 square feet per ton of pulp per 24 hours. The corduroy is changed about every four hours, the concentrates washed into a box and further concentrated on shaking tables; the gold in these concentrates is then amalgamated with mercury in a clean-up pan. The mercury is distilled off by heating the amalgam in a retort; the gold is then melted in crucibles with the aid of a little flux and poured into moulds.

The tailings from the corduroy tables carry a large percentage of the gold, much of it very finely associated with gangue minerals. This gold is extracted by the cyanide process. In large plants there is a tendency nowadays to eliminate the preliminary stage of amalgamation, and all the ore, after very fine grinding down to less than 200 mesh, is leached with cyanide solution. The leaching is done in tanks, the pulp being mechanically agitated, the solution is then filtered off and the gold precipitated in boxes by addition of zinc shavings to the solution. The gold is finally melted in crucibles and poured into moulds. The total recovery of gold by this process may be as high as 96%.

At some small mines in India the concentrates from the corduroy tables are merely amalgamated, and as much as 50% of the gold has been lost in the tailings. Cyaniding is recommended even for these small mines, but it cannot be too strongly emphasised that successful treatment of gold ores requires considerable technical experience.

Graphite.—Very little graphite is normally mined in India. Exceptionally rich deposits containing over 90% graphite, such as those in Ceylon, are rare, the majority are of much lower grade. Amorphous graphite used in foundry work may merely require fine grinding. Beneficiation may consist simply of hand-picking and winnowing; the usual method is to wash the crushed and ground mine product in tanks as described under *China clay*, thus separating the graphite from accompanying grit, etc., but the method is very wasteful. Various mechanical processes are used in other countries, and nowadays concentration of graphite may be effected by flotation. Because of the small market available in India it is doubtful whether flotation would pay in normal times, although it would certainly yield a high grade graphite. Pure graphite can be produced only by chemical means, the impurities being dissolved with hydrofluoric acid.

Gypsum.—As gypsum is a very low-priced material the mined product must be more or less pure. The mineral is crushed and marketed for use as a flux or as a retarder in cement. When finely ground it may be used for agricultural purposes, in paint, paper, etc., and for the manufacture of calcium sulphide or sulphuric acid. Ground gypsum may be calcined in special kilns to remove half of its chemically combined water; the resulting calcined gypsum (plaster of paris) is used in all kinds of special plasters.

Iron ore.—The reduction of oxide of iron, in iron ores, to metallic iron is effected by smelting with carbon. Impurities present, mainly silica and alumina, are converted into slag, limestone being added as a flux. The mine ore, suitably crushed, is charged into a blast furnace with coke and limestone; the coke supplies not only the fuel to melt the charge, but also the necessary amount of carbon; the slag is a complex calcium alumina silicate. The molten iron sinks to the lower part of the furnace and is tapped off as pig iron. By controlling the original charge the pig iron may be adjusted to a composition suitable for certain purposes, *e.g.*, a high phosphorus pig is useful for foundry work.

About 75% of the pig iron smelted in India is absorbed in the manufacture of steel. For this purpose several processes may be

used according to the type of steel smelted. In the open hearth process, the charge consists of molten pig iron and steel scrap and is heated by producer gas; impurities are removed by adding lime and iron ore, and the steel is finally cast into ingots. In the Duplex process, molten pig iron is charged into acid (silica)-lined Bessemer converters, and part of the impurities removed by blowing air through the molten metal. It is then transferred to basic-lined tilting furnaces where it is further purified and adjusted to the necessary composition before being cast into ingots.

The ingots are rolled into billets, bars, plates, sheets, structural sections, rails, etc.

Kyanite.—As mined in India kyanite is practically pure and needs merely to be hand-sorted to reject material high in iron. Before it can be used for ceramic purposes or in refractory bricks it is necessary to heat it to a temperature of over 1540°C, thus converting it into a material known as mullite. This is then crushed and ground, bonded with clay, moulded to the shape required, and fired in kilns. Besides its use in high quality refractory bricks, particularly for glass melting furnaces, it is also used in special porcelain. The use of kyanite in India has been mainly of an experimental nature to date partly because of the high price of the raw material.

Lead-zinc.—No lead is at present smelted on a permanent commercial scale in India, the nearest smelters being at Namtu, Burma. Modern treatment of lead-zinc ores is briefly as follows:

The ore is crushed and ground and concentrated on shaking tables. The tailings are then treated by flotation as described under *Copper*. In this way, from a lead-zinc ore having the following typical composition: 8·3% lead, 9·9% zinc, and 6·1 ozs silver, two concentrates will be formed, one a lead concentrate assaying perhaps 39·4% lead, 10·8% zinc, and 27·3 ozs silver, the other a zinc concentrate assaying 52·1% zinc, 2·3% lead, and 2·8 ozs silver. Another typical ore, assaying 15·2% lead, 11·7% zinc, and 8·8 ozs silver, yields a lead concentrate assaying 74·7% lead, 3·9% zinc, and 39·9 ozs silver, and a zinc concentrate assaying 51·6% zinc, 1·7% lead, and 2·5 ozs silver.

The smelting of lead ores is divisible into three main stages: (*a*) roasting or sintering of the concentrates to remove sulphur and to produce a material suitable for treatment in the blast furnace, (*b*) reduction of the sintered ore in the blast furnace to bullion, consisting of lead, silver and gold, and such impurities as copper, antimony and arsenic, (*c*) refining of the bullion, yielding a lead product 99·99% fineness, with by-product gold, silver, copper matte, and antimony and arsenic dross.

Zinc concentrates are roasted and leached to take the zinc into solution, various impurities precipitated, the solution neutralised and the zinc then precipitated electrolytically on aluminium cathodes, melted and finally cast into slabs assaying 99·78% zinc. By-products such as cadmium may also be obtained. Sulphuric acid manufacture is invariably an accompaniment of roasting of lead and zinc concentrates.

The above description of the extraction of lead and zinc is merely a summary of the main procedure involved. The metallurgy of lead and zinc is extremely complex and the technical detail involved requires a lifetime study.

Limestone.—The treatment to which quarried limestone is subjected will depend upon the purpose for which it is required. Limestone to be used as a flux in iron and steel smelting is merely crushed and screened to size before despatch to the works. Where it is required for conversion into lime, the limestone is crushed and screened to size and then calcined in kilns to quicklime. Generally the kilns are situated close to the quarries. The calcined product may be sold either as quicklime, or slaked with water and converted into hydrated lime. Both quicklime and hydrated lime are generally bagged for marketing.

In the manufacture of Portland cement the limestone is ground to size, mixed with the required amount of clay to bring it to the correct composition, and burnt in rotary kilns to a clinker. The composition of such a mixture is generally approximately 75% calcium carbonate, 10% silica, 10% alumina and iron oxide, and 5% impurities such as magnesia and alkalies. The resulting cement is a mixture of several compounds: calcium silicates, calcium

aluminates, calcium ferro-aluminates, etc., which harden or set when mixed with water and form new compounds. Other special cements are made, such as alumina-cements from bauxite and lime.

In India the raw limestone is used as mined without improvement. In other countries flotation is being increasingly and successfully introduced to improve the quality of raw limestone for many purposes in which a particularly pure product is necessary.

Lithium.—Lepidolite is not mined in India, but the mine material would merely require hand-picking and crushing to size.

Magnesite.—When used for the manufacture of refractory bricks crude magnesite is dead-burnt in kilns at about 1600°C, then ground to a fine powder in mills, and moulded into bricks, using a few percent of iron oxide and a little caustic magnesia as a bonding material. The bricks are then fired in kilns, a process which requires close attention to detail mainly because magnesia cannot withstand any load during burning.

Caustic magnesia is made by calcining magnesite at about 1200°C and is used for special cements.

It is possible to produce metallic magnesium from magnesite by the thermal reduction of calcined magnesite with suitable reducing agents. In one process the magnesian oxide is heated with calcium carbide in vacuo; the metal so obtained is re-melted and refined with suitable fluxes of which anhydrous magnesium chloride is usually the base. Magnesium is also made by electrolysis of fused anhydrous magnesium chloride derived from brines. In the Pidgeon process dolomitic lime is reacted under vacuum with ferrosilicon in a retort. The crystalline mass of magnesium, 99·98%, is later melted under flux and poured into ingots.

Manganese.—Apart from breaking to size and sorting into grades according to the assay value, manganese ore in India is generally marketed without further treatment. Low grade ores may be improved by washing or jigging, or, in some places, by flotation. Some Indian ores could undoubtedly be improved and at least one firm has been experimenting recently in that direction.

For use in dry batteries or in the glass, ceramic, and chemical industries, the ore must be finely ground. In metallurgy some

crushing is required if the ore is to be added direct to the blast or steel furnace. In the manufacture of ferromanganese, for steel-making, the ore is reduced in a blast furnace in the same manner as for the production of pig iron.

Mica.—The crude mica is brought from the mines to the cutting sheds and rifted into slabs up to ¼-inch thick. Flaws are then cut away by means of a sharp sickle; the resulting 'blocks' of mica are irregular in shape, up to ⅛-inch thick and average 15–25% of the original crude. The blocks are sorted into sizes and then according to quality, a certain amount of further trimming being done during sorting. Much of the better quality of block mica and the larger sizes of poorer quality block are exported in this condition. Some is cut to definite shapes in India, or split to definite thicknesses, say ·008 to ·012 inch, for specific purposes. A certain amount of the best quality mica is split into 'condenser films', with thicknesses of ·001 to ·003 inch, and these are then cut to shape for use in condensers. The poorer quality block mica is converted into splittings by separating the mica along the cleavage into laminae averaging about ·001 inch in thickness. The larger sizes of splittings are assembled into 'books', analogous to thin packs of cards, each containing perhaps 50 splittings according to the original thickness of the block. The smaller sizes of splittings are sold 'loose'. The number of splittings made annually in India is normally perhaps 40,000 million.

Splittings are manufactured into *micanite*, by bonding them with special bonding material, such as shellac, glyptal, etc., and heating under pressure. Various kinds of micanite are manufactured according to the type of electrical insulation required—micanite board, micanite cloth, micanite paper.

Scrap mica is finely ground in mills, and the powder used for many purposes, sueh as for rubber filler, roofing, wall-papers, lubrication, etc.

The manufacture of micanite and ground mica requires development in India.

Mineral pigments.—Some natural pigments may be improved by washing to remove grit, clay, etc. Before marketing, most

ochres have to be dried, ground, and sieved. In some cases the colours may be improved by calcining.

Monazite.—Beach sands containing monazite and ilmenite are concentrated on shaking tables, see under *Titanium.* The monazite concentrates contain 8–10% thoria which is extracted chemically for use in gas mantles.

Nickel.—Should nickel deposits be found in India they will need to be concentrated by the same process as for copper. The concentrates would then be smelted. Refining is best done electrolytically.

Nitrates.—Potassium nitrate (with also sodium sulphate and other salts) is collected from the surface of the soil in North Bihar and United Provinces. The amount of saltpetre in the soil collected varies between 1 and 29% but is normally less than 5%. Some of these nitrate-bearing soils are used directly as manures but most are used for the extraction of saltpetre. Wood ashes are mixed with the soil in order to decompose any calcium nitrate present and the salts are then dissolved in water. The liquor may contain 15·25% sodium chloride, 7·24% saltpetre, and small quantities of other salts. On evaporation the sodium chloride separates out first, the saltpetre later. This crude saltpetre, containing up to 25% of impurities, may be used as a fertiliser or sent to refineries for the manufacture of gunpowder.

Petroleum.—The crude oil is subjected to heat treatment and, by a process of fractional distillation, divided into various light oils (motor spirit), medium oils (kerosene), and heavy oils (lubricating oil), with residual waxes in the case of oils having a paraffin base and fuel oils in the case of those having an asphaltic base. By heat treatment under high pressure the crude oils may be 'cracked' to form petroleum products of particular qualities, such as aviation spirit and motor spirit. By a close control of the various processes the proportions of the different fractions produced can be adjusted to some extent to the market requirements.

Phosphates.—Production of phosphates in India has been very small. When used for agricultural purposes the apatite is

ground to a fine powder. For metallurgical purposes the mineral is merely crushed to size.

Precious stones.—The majority of precious stones in India are washed from detrital deposits. The gravels and sands are washed to remove mud, coarse material is rejected, and diamonds or other stones in the final concentrate are then picked by hand. In South Africa the washed concentrates are passed in a current of water over greased tables, the precious stones becoming embedded in the grease.

The rough gems are cut approximately to shape by rotating discs charged with diamond dust, then the facets are polished on soft iron laps charged with diamond dust and olive oil.

Salt.—Much of the salt produced in India is manufactured by the Salt Department of the Central Government; a certain amount is manufactured by companies and private concerns which pay excise to Government.

The salt rock which is mined in northwest India is marketed without any treatment. The salt from inland lakes, *e.g.*, Sambhar Lake, or from sub-soil brines as in the Rann of Cutch, or from the sea water as near Karachi or on the Coromandel Coast, is precipitated by solar evaporation of the salt solutions. In general, the process is in two stages: (*a*) the solution is concentrated by evaporation in large 'condensers'—several acres in extent—until a degree of concentration is reached close to that at which the salt would separate out, and (*b*) the brine is then run along channels into carefully prepared shallow 'evaporating pans', to a depth of about 3 inches, where the salt almost immediately begins to precipitate in the form of small crystals, and is scraped from the floor of the pans as required. The condensers and evaporating pans are constructed on flat land merely by raising the necessary bunds, the floor of the pans being carefully prepared with clay so that there will be no leakage and at the same time no possible contamination of the salt. The salt is generally marketed without further treatment. The refined salt used in food industries is made from brines treated in vacuum evaporating pans.

Silica and sand.—Sands used for building construction are sized by simple screening. Filter sands require to be screened and washed. Foundry sands are required in various grades of fineness, and, after careful screening and perhaps washing, they are mixed with clay and other ingredients according to the particular type of castings to be made. Abrasive sands generally are screened before use. Glass sands must contain as little iron as possible and they may be derived either from detrital deposits or from sandstones; if from the latter the rock must be friable or easily crushed, and commonly the rock is simply broken down by wooden mauls at the glass works, but careful screening and sometimes washing is necessary.

For the manufacture of silica bricks, pure quartzite is used. The quartzite is crushed, then ground with the addition of water and lime to serve as a bond. The ground silica is then moulded into the desired shapes, dried, then burnt in kilns for about twelve days and cooled for a similar period.

Quartz-schist and quartzite for use in Bessemer converters are merely shaped by masons.

Slate.—The slate from the quarry is first split into slabs of convenient thickness and trimmed to size, then split into sheets of the required thickness. In India most of this work is carried out by hand but mechanical methods are also used both for cutting the blocks to size and for cleaving. The amount of waste generally exceeds 60% of the quarried slate.

Soda.—Soda is collected from Lonar Lake, Berar, and from shallow lakes between the sandhills in Sind. The Sind industry is quite considerable, the soda being required for baking biscuits, washing clothes, hardening treacle, the preparation of tobacco, and for soap-making. The material marketed contains up to 33% sodium bicarbonate and up to about 50% sodium carbonate, with very variable amounts of sodium sulphate. The soda derived from alkaline soils on the Gangetic plains is obtained along with potassium nitrate. Most of the soda ash and salt cake used in industry is manufactured from salt.

Strontium.—Apart from careful hand-picking and washing to remove attached debris, strontium minerals require only fine-grinding before marketing.

Sulphur.—Natural crude sulphur may contain only 35% sulphur and is improved by sublimation in kilns, distillation in retorts, or by liquefaction in steam-heated vessels to over 99% sulphur. Flotation methods may also be used.

Pyrite as used in industry is either a by-product of the concentration of other sulphide ores and already concentrated, or is from a pyritic ore sufficiently high in sulphur (over 35%) to be used direct for the manufacture of sulphuric acid. Indian acid manufacturers prefer to use natural sulphur rather than the pyrite available in the country.

Talc (steatite).—When required as a refractory lining in furnaces, or for acid-proof tanks, vats, etc., steatite is cut into blocks of the requisite size and shape. Talc can be readily turned on lathes or cut into shapes which are then fired in furnaces at 1800°F and converted into a material which is harder than steel—this product, called 'lava', is used particularly for gas burner tips and electrical apparatus.

When used as a filler in paper, etc., as a lubricant, or cosmetic, or in ceramics, talc must be ground to a fine powder (300 mesh) in dry mills, then air separated. A typical mill grinding 6 tons per hour (50 tons per day) requires 80 h.p.

Titanium.—The ilmenite-bearing beach sands of Travancore are concentrated on wet tables to remove quartz sand, then, after drying, the ilmenite is removed by magnetic separators, leaving monazite, zircon, rutile, garnet, etc. The ilmenite concentrate contains 53–60% TiO_2. The monazite and zircon are then further extracted.

In India the attempt has not yet been made to manufacture white titanium oxide from ilmenite. There are several patented chemical processes, each requiring careful control of the various stages.

Tungsten.—Ores of tungsten vary widely in composition and require to be concentrated up to 60–65% WO_3, which is usually

done on shaking tables. At Degana, in Jodhpur, where there is little water available, concentration until recently was effected by hand-picking and winnowing, the final product containing 66–70% WO_3.

Vanadium.—The vanadium-bearing titaniferous iron ores in Singhbhum and Mayurbhanj are a possible source of vanadium in India. They contain variable percentages of V_2O_3, ranging from less than 0·5% to nearly 8%, but probably averaging between 1·0 and 1·5%. An economically successful method of treating these ores is awaited. The most promising line of investigation would appear to be a smelting process for the recovery of ferro-vanadium.

Zircon.—The beach sands of Travancore contain about 6% zircon and the mineral is obtained as a by-product during concentration of ilmenite, see under *Titanium*. The zircon concentrates may contain 55% ZrO_2.

Zinc.—Should zinc be mined in India, the ore will be concentrated by flotation and the concentrates treated as described under *Lead*.

CHAPTER X

MARKETING AND PRICES

The methods of marketing minerals vary widely. The managing agency system in India controls the marketing of a number of minerals; not uncommonly the same managing agents control the activities of both the company which mines the mineral and the company which consumes it. However, perhaps the greater proportion of the minerals produced in India are outside of the control of managing agents. Some manufacturers have their own mines which are able to supply mineral up to the capacity of their works. In other cases the mineral may have to be purchased from smaller miners, and not uncommonly it may be necessary to blend the mineral from various sources according to a particular specification. Many miners are too small to sell direct to manufacturers and may sell through dealers; this may lead to complex trade ramifications as in the mica industry where the trade is worldwide. Some miners may sell their product as it comes, others may divide the mineral into grades, and sales may be based on quite rigid specifications, with bonuses or penalties according to whether consignments are above or below the specification limits. There is no organisation in India to assist the small miner to get into touch with consumers, or of likely consumers to get into touch with small miners, but some form of Mineral Exchange would undoubtedly be advantageous.

Prices for some minerals may show little variation over a long period of years, for others the yearly range may be considerable. For a few minerals the range in sale price may be 100% but for the majority it may be only 10–20%. The place at which prices are quoted depends upon whether the mineral is to be exported or is to be consumed locally. Exported minerals are generally purchased *f.o.b.* Indian ports, whereas prices of locally consumed

minerals may be quoted either *f.o.r.* nearest railway, or at the consumer's works. Normal peace-time prices are noted here.

Abrasive materials.—In India the marketing of abrasives is entirely casual, mainly because there is no very great demand for the various materials. Consumers normally deal direct with small miners or contractors and purchase according to their current requirements. Enquiries regarding such materials as millstones and grinding pebbles are very common indeed and, although materials are known to be available, it is often difficult to obtain supplies. A market for abrasives is clearly expanding in India and there would appear to be scope for a company which would specialise in securing supplies from all parts of the country. It is not at all improbable that if the market requirements were thoroughly examined and encouraged, a locally established artificial abrasive industry could compete with imported materials. It is not possible to quote here reliable prices of the wide variety of abrasives which are casually marketed in India.

Asbestos.—So little asbestos has been mined in India that there is no organised market and most of the product is sold locally direct to consumers. Supplies are mainly from overseas and manufacturers' requirements until recently have been spasmodic. A certain amount of asbestos has been exported from India to London and Belgium. The unreliability of the mineral's occurrence, and of the market, makes asbestos mining in India a most speculative undertaking. As much as £70 per ton has been paid in London for Madras asbestos but prices paid for crude asbestos in India, up to Rs210 per ton, have not been an inducement to expansion in output. Imported Canadian asbestos fibre ranges in price according to quality from Rs0-9-6 to Rs6-8-0 per lb. The total imports of manufactured asbestos goods into India range between Rs20 and Rs30 lakhs per annum.

Barite.—Indian barite has not as yet been marketed in considerable quantities. There is scope for improvement in the treatment of the mine product by bleaching and fine-grinding. Such material as is produced is sold direct to oil companies for use in rotary drilling, and to paint manufacturers and to other con-

sumers. The price of imported barite in India ranges between Rs60 and Rs100 per ton. The total consumption in normal years is up to about 12,000 tons, of which a little over half is produced in the country. The sale price of Indian barite varies according to grade, but the Calcutta price has been Rs30 to Rs50 per ton for lump barite, and Rs100 and over for fine-ground barite.

Bauxite.—The small amount of bauxite absorbed in India by oil companies for purification of kerosene, by chemical companies and by refractory brick works, has been obtained through small contractors. The alumina and aluminium works which have been erected to operate in this country will obtain their bauxite supplies from their own mines. The annual tonnage consumed in India has ranged from 1,000 tons to over 9,000 tons, and prices have also ranged from Rs2 to Rs8 per ton at the mines.

Bentonite.—Supplies can be obtained direct from either Kashmir State or Jodhpur State darbars. Prices vary with the quality and may be as much as Rs20 per ton at the mine.

Beryl.—The price of beryl is determined by requirements in the United States and in Europe, but is generally between £8 and £10 per ton *c.i.f.* Prices considerably over Rs120 have recently been paid, *f.o.b.* Indian ports. Shipments are made direct to consumers.

Chromite.—As the consumption of chromite in India is rather small, the principal market is overseas. The overseas market in normal times is under the close control of a powerful ring of producers, and outside miners often find difficulty in marketing their output. As a rule, purchasers in India contract to buy chromite direct from the producers according to analyses, bonuses being generally given for excess of Cr_2O_3. Overseas trade is either direct to consumers or through agents or dealers.

Prices vary according to chrome oxide content. The *c.i.f.* prices United Kingdom ports may be about £8 per ton for 48% ore, £5-17-0 per ton for 45-46% ore, and £4-15-0 per ton for 42–44% ore. Prices in India for first grade ore may be Rs25 to Rs40 per ton *f.o.r.* nearest station, but the usual price delivered at the firebrick works in the Raniganj coalfield before 1939 was about Rs32 per ton; Singhbhum ore is purchased at Jamshedpur

for about Rs50 per ton. Chrome refractory bricks are quoted in India at Rs125 per ton. Ferrochrome in London may be about £60 per ton best grade.

Clays.—Some of the firebrick manufacturers obtain fireclays from their own mines, but purchases are also made from contractors. The average price at the works is about Rs4-8-0 per ton. Firebricks are sold according to grade, the price at the works being Rs5 to Rs15 per hundred.

The majority of china clay producers market their clay at paper and cotton mills. Some pottery manufacturers have their own clay deposits. Prices up to Rs30 per ton have been paid for the best quality Indian white clays. About 20,000 tons of china clay are still imported annually at a price well above the average for Indian clays.

Other pottery clays, mainly for tiles and earthenware, are generally obtained by the manufacturers from deposits close to their works. This industry has considerable scope for development, as earthenware, etc., to the value of over Rs50 lakhs is imported annually.

Coal.—The principal consumers of coal in India are the railways, which normally take over 30% of the production, and the iron and steel and engineering industries which take approximately 25%. About 10% accounts for colliery consumption, about 6% is used for bunkering, and the remainder is required for cotton mills, jute mills, brick and pottery kilns, etc. The railways and iron and steel companies have collieries of their own but are also extensive buyers. Many collieries are grouped under various managing agencies, each of which has a widespread selling organisation. Many important purchases of coal are made by tender, but much coal is sold direct or through agents, middlemen, or brokers. Many of the small collieries are dependent on the success of their tenders for the annual railway contracts, the majority depend on brokers for their sales.

The price of coal varies considerably according to the grade and these prices are subject to wide annual fluctuations. Moreover, the price varies between different coalfields. During a typical

recent year the average price per ton of coal at the pit's mouth was: Assam Rs8, Bengal Rs3-12-0, Bihar Rs3-4-0, Central India Rs4-2-0, Hyderabad Rs4-4-0. The prices are absurdly low as compared with coal prices in other countries but this is mainly due to competition amongst the coal companies. Probably the prices ruling in 1924-25 would appear to be a fair gauge of the real market value of this commodity if it is to be worked and marketed efficiently; for Bengal and Bihar this price would appear to be about Rs6 per ton.

Columbite-tantalite.—As there is no regular production the price of this group of minerals varies widely. In 1937 a parcel of 11·2 cwts of tantalite was valued at £23.

Copper.—At present copper is smelted by only one company in India, and the brass and copper produced are sold through a Calcutta agency. The Indian price fluctuates with the overseas price of copper and may range from an average of Rs500 to Rs1,000 per ton in different years. Brass is sold at a somewhat lower price.

Feldspar.—Crude feldspar is sold at an average pit's mouth price of Rs7 to Rs9 per ton.

Fluorspar.—The average price paid for good quality fluorite imported into India has been about Rs85 to Rs90 per ton *c.i.f.* Calcutta.

Fullers earth.—The pit's mouth price of fullers earth has varied from Rs1-8-0 in Jubbulpore to Rs10 per ton in Rajputana.

Gold.—Gold bullion is purchased by the Bombay mint. The price paid for fine gold has progressively increased from Rs77 to Rs106 per ounce since India went off the gold standard in 1931.

Graphite.—Most of the Indian graphite is sold to foundries, some is absorbed in the manufacture of crucibles. Prices vary widely, better quality material is sold for over Rs50 per ton *ex-mine* and even Rs100 per ton has been paid. Beneficiation by flotation might make a decided improvement in the industry in India.

Gypsum.—Consumers of gypsum in India either mine their own deposits or purchase direct from small miners. The price at the mine for crude gypsum ranges from Re1 to Rs10 per ton with an average of about Rs2-4-0.

Iron ore.—The iron and steel smelting companies have their own iron ore mines, although a certain amount may be purchased from other mine owners. The smaller mine owners have exported most of their ore in the past; the sale price normally ranges up to about Rs2 per ton *f.o.r.* nearest siding. The price of foundry pig iron varies according to grade, but has averaged approximately Rs90 per ton recently.

Kyanite.—Almost the whole of the kyanite mined to-date in India has been exported. Shipments are made direct by the mine owners to the manufacturers of mullite bricks in England, or to the manufacturers of refractories and high grade porcelains in America and Europe. The *f.o.r.* price has been as high as Rs39 per ton but the average appears to be about Rs20. Calcined kyanite is sold in England for about £11 per ton.

Limestone.—Cement manufacturers have their own limestone quarries. A considerable amount of limestone within reasonable distance of the iron and steel smelting centres is sold as flux; large tonnages are converted into lime. The sale price at the quarries is generally about Rs1-6-0 to Rs2-6-0 per ton. Portland cement may be sold for Rs35 to Rs40 per ton *f.o.r.*

Magnesite.—Consumers purchase their magnesite requirements direct from the mine owners in India. The price has been quoted at Rs6 to Rs8 per ton at the mine, but the cost delivered at the firebrick works in Bengal and Bihar, a distance by rail of over 1,300 miles from Mysore, is approximately Rs45 per ton.

Manganese.—The greater part of India's manganese production is exported. The principal consumers abroad normally purchase their manganese ore requirements direct from the producers and contracts may extend over a considerable period. Smaller consumers may obtain their supplies from importers or through brokers. In India requirements are purchased direct from producers, but the iron and steel works also have their own mines. The price depends on the demand and on the grade of ore. For first grade ore prices have ranged between Rs14-8-0 and Rs45 per ton *f.o.b.* Indian ports. Penalties may be charged for silica and phosphorus which may be present above specified limits.

Chemical ore, as used in the glass industry and in dry batteries, may range between Rs50 and Rs250 per ton.

Mica.—In Bihar the two centres of trade for mica are Kodarma and Giridih, where Rajputana mica is also normally marketed. In South India the mica market is Madras. The larger mica producers are also dealers and exporters, a few dealers and shippers have no mines, and most of the medium and small producers sell their mica in the local market to dealers.

Until recent years most of the mica exports went to agents and brokers in London from where the mineral was re-distributed to the principal consuming countries. London was, therefore, the world's marketing centre for mica. Since about 1928 the larger Indian exporting companies have shipped direct to the principal importing countries, mainly through their own agents who have kept on hand quite considerable stocks. The small exporters still find it necessary to depend on brokers to market their mica and consumers are able to rely upon the brokers' guarantee of quality of inspected consignments. One or two of the larger companies have had such long-established dealings with the principal electrical insulation manufacturers that a large part of their business includes a more or less direct and steady shipment of mica for definite purposes.

Prices for different qualities and sizes of mica vary within wide limits. Prices of Rs65 per lb *f.o.b.* Calcutta are not unknown for special sizes of clear and superfine block, whilst small sizes of densely stained quality may be less than 6 annas per lb. Scrap mica has normally averaged about Rs50 per ton.

Mineral pigments.—Ochres are generally sold direct to consumers, mainly for the manufacture of paints, and for colouring cement, etc. The price varies, but is generally between Rs4 and Rs8 per ton at the mine. There is scope for considerable expansion of the local paint industries, as annual imports of paints exceed one crore of rupees.

Monazite.—Output of monazite is normally despatched direct from the producers to the manufacturers of thorium nitrate. The

price of the mineral has progressively decreased in recent years and before the war was about Rs45 to Rs50 per ton.

Nitrates.—The saltpetre refineries in Northern India are under the supervision of the Northern India Salt Revenue Department; much of the production is exported. Prices of saltpetre vary between about Rs10 and Rs14 per cwt. A considerable amount of sodium nitrate is imported annually.

Phosphates.—Phosphatic nodules are generally sold direct to planters as fertilisers, the price ranging from Rs5 to Rs15 per ton. Apatite, when mined, has been sold direct to the iron smelters or for agricultural purposes at a price around Rs20 per ton.

Salt.—Salt is distributed through licenced dealers, generally more or less within reasonable distances of the areas of production. However, in Bengal most of the salt is imported. The duty on salt is Rs1-9-0 per maund, this is to be added to the producers' price which ranges from Rs2-4-0 to Rs3-8-0 per maund in various parts of India.

Sand and silica.—Consumers of sands generally obtain their requirements from small contractors, if possible close to the locality where the sand is required. Prices vary according to the type of sand, and the purpose for which it is used. Good quality glass sands may be sold for Rs7 per ton *f.o.r.* nearest station to the mine. Building sands, etc., may be sold for less than Rs2 per ton.

Soda.—A ready local market exists for the alkali salts produced in India and consumers normally obtain their supplies direct. Sind alkali salts are sold in the local bazaars, some is even despatched to Bombay. The price at the soda lakes may vary from Re1 to Rs2 per maund and may be up to Rs5 in Karachi. Manufactured soda ash may be up to Rs6-4-0 per cwt. There is a large import trade in such materials as sodium nitrate, caustic soda, sodium carbonate, and sodium bicarbonate, so that scope for increased local production is apparent.

Strontium.—English prices of celestite are of the order of 30 shillings per ton *f.o.r.* port of shipment.

Sulphur.—Until recently sulphur was not produced in India. The average pre-war price for refined sulphur in Calcutta was about Rs85 per ton.

Talc (steatite).—Talc powder may be sold direct to soap-makers and to paint, paper, cloth, and rice mills. The price of crude steatite varies according to its quality and the purpose for which it is to be used. Good quality material suitable for grinding into powder may be sold for upwards of Rs20 per ton; prices as high as Rs100 per ton are not unusual for blocks cut for ornamental purposes.

Titanium.—The whole of India's ilmenite production is exported to manufacturers of titanium white overseas; the price of concentrates at the mills is about Rs6 per ton, or £2 to £2-10-0 London, and $10 to $12 U.S.A. ports.

Tungsten.—Up to 1939 the price of wolfram varied widely and was governed by the American and European demand but was of the order of 50 shillings per unit of contained tungstic oxide, *c.i.f.* British ports. For a tungstic oxide content of 66% this is equivalent to £150 per ton of ore.

Zircon.—Zircon concentrates from Travancore are sold for £8 to £10 per ton *c.i.f.* London.

CHAPTER XI

CAPITAL REQUIREMENTS

The capital required for the efficient working of a mineral deposit will depend upon the scale of operations permitted by the positive and probable reserves which may be available. Obviously it is unwise to erect a plant so large that it is capable of working out the deposit within three or four years. It is preferable to install a plant of such capacity that a profitable rate of working over a considerable number of years is assured on the likely reserves. A further factor governing the rate of working may also be the market demand for the particular mineral. There are, of course, certain mineral deposits which require little or no plant to work them, and which may advisedly be worked as rapidly as the market can absorb the output.

When the optimum rate of production has been decided, capital will be required for the following six principal purposes:

(*a*) To bear the cost of prospecting necessary to prove the minimum reserves. As far as possible the reserves prospected should at least assure the return of capital, but in certain deposits, such as gold, lead-zinc or copper lodes, the immediate establishment of the full reserves would be impossible.

(*b*) To pay for the development of the mineral deposit by shafts or adits, crosscuts, drives, winzes and rises, thus making it accessible for production.

(*c*) To pay for plant and other equipment, water supply, mine buildings, housing and other buildings.

(*d*) To pay for land acquisition and general lease expenses.

(*e*) To secure funds (*i.e.* operating capital) to enable operations to be undertaken for a period of at least three months, bridging the interval between commencement

of production and commencement of marketing. The amount will normally comprise working costs and supplies for the period.

(*f*) To pay for broker's charges and other incidental expenses necessary whilst the company is being floated.

In most mines which require considerable capital, funds for development and for plant and buildings represent by far the principal items. Hence it will be readily appreciated that on mines where little or no plant is necessary and where the small supervising staff requires the erection of only a few buildings, the capital requirements will be little more than the cost of labour and supervision for preparing the mine up to the stage of production, with also sufficient funds to secure the accumulation of about three months' stocks.

Small quarries, whether on ochre, clay, iron ore for export, kyanite, manganese, coal, or other material requiring no crushing and merely simple treatment such as washing, may require only very small capital, perhaps even less than Rs20,000. But wherever machine-drills, compressors, crushers, etc., are essential, the capital cost will mount accordingly.

For underground properties on the same minerals capital costs will be greater, because shaft-sinking and other development charges are often considerable, and winding engines and shaft headframes are essential. The additional amount of capital for these purposes will vary, of course, with the extent of the reserves to be developed and with the daily tonnage which it is intended to produce.

Where it is decided to treat the mineral in order to extract the metal, as in copper or iron and steel smelting, extensive treatment plant may add more to the capital requirements than all of the capital tied up in the mine itself.

It may be possible to open up a medium-sized mica mine for Rs5,000 to Rs10,000, but as the depth and scale of the necessary operations increase, requiring winding plant, machine-drills and

compressors, the capital expenditure may mount to Rs70,000 or even to Re1 lakh before mica is profitably produced. Similarly, a small underground coal mine with headgear, winding engine and other essential plant, may require up to Re1 lakh to put it into production but this may increase to over Rs10 lakhs for medium and large properties; the average production of coal per rupee of capital invested in collieries in India is about 0·3 to 0·4 tons per annum.

A large copper mine equipped to produce 1,000 tons of ore per day and with reserves developed sufficient for 3–5 years may require a capital of perhaps Rs35 lakhs. Plant for transport of ore to the mill, and for milling, concentrating, and smelting, may require a further Rs35 to Rs40 lakhs. If the metal is to be converted into brass a rolling mill is required. The capital of the Indian Copper Corporation, with a production of 1,000 tons of ore per day and 6,000 to 7,000 tons of copper per year, most of which is converted into brass, is £900,000.

For a great iron and steel works, with production of metal exceeding a million tons per annum, the capital invested may be many crores of rupees. The requirements for the iron ore mine itself may be only a few lakhs, to which may be added, however, many lakhs, perhaps crores, invested in coal mines, limestone quarries and other subsidiary mineral properties such as fireclay, manganese, and chromite.

A recurrent subject of amazement to the writer is the inability with which many business men, who may be noted for their shrewdness in other lines of business in India, are unable to form a clear judgment of the capital requirements of a prospective mine. They have come to the writer for advice, with expectations of immediate vast capital expenditure on plant, and visions of enormous production, before even adequate reserves have been developed. No inconsiderable difficulty has at times been experienced in convincing them that there was, as yet, no basis for their rosy visions, and that the chances of failure in any mining gamble should always be reduced to a minimum before the full capital is raised. Much needless loss

in mining would be avoided if, in the early stages, the capital raised is the bare minimum to prove the size of the ore-body, with a small plant for current production, fresh calls being made on the shareholders as necessary. If a failure, the loss is not great, if a success the requisite further capital can be raised later in step with the requirements of the moment.

CHAPTER XII

MINE PLANS

Although for the majority of mines of any size in India the owners keep plans of some kind, it is rare to find such plans prepared on the smaller properties. This is generally because of diffidence in incurring the pay or fee of a mine surveyor. On many small properties, however, the services of a surveyor would be scarcely necessary, a few simple tape measurements would suffice, but the average non-technical owner might find difficulty in transferring his measurements to paper. Mine owners would be well advised to keep plans of their mines, however small the latter may be, for they are a very useful aid in guiding the course of mining operations.

Mine plans are of two principal types—(*a*) those on which the mine workings are delineated, and (*b*) those showing the geological features. The former are common to most mines on which plans are kept, the latter are unfortunately very rarely prepared in India.

In surface mining the plans should preferably show the surface topography (contours, streams, etc.), and all details of lease boundaries, roads, paths, buildings, tram lines, pipes, open-cuts, working benches, dumps, etc. The scale used will be determined by the size of the property and the detail required. By dividing the area into squares, any particular point may be represented by coordinates for purposes of reference.

In underground mining two separate groups of plans should be prepared: (*a*) those showing the surface features, and (*b*) those representing the underground workings in detail. The more important underground workings should also be delineated on the surface plans in order to indicate the position of underground workings relative to surface features. The scale to be used for surface plans will, of course, be governed by the size of the property and the degree of detail required. For underground plans the scale

will likewise be dependent upon the extent of the mine workings and the amount of detail to be shown; for a small mine a scale of 10 feet to one inch may be suitable, but for a large mine a scale between 40 feet and 100 feet to one inch is generally adequate.

Where coal seams are flat-dipping a plan of the colliery workings normally suffices to represent all the underground features. In metalliferous and other mines, however, the workings should be represented by both plan and longitudinal section; in addition, a series of transverse sections across the trend of the deposit and workings assist in providing a clear picture of the mine. Each level should be delineated in a different coloured ink, and, for a mine where the levels are more or less vertically below one another or where the detail on each level is great, it is advisable to map each level on a separate sheet.

To be of any real use mine plans should be brought up-to-date periodically—during the author's visits to mines in India owners have commonly quite proudly produced their mine plans as an indication of their modern methods but on examination it has been not at all unusual to find that the plans had not been kept up-to-date since they had been prepared twelve months or more previously!

Simple geological features, such as faults and dykes, are commonly shown on colliery plans, and indeed that is all the geological information necessary in most coal mines. In metalliferous and other mines in India the geological features are generally much more complex, and the real understanding of a deposit may depend upon detailed mapping of the geology. However, in India, it is very rare to find that detailed geological plans have been prepared of any particular mine; of course the main reason for this deficiency is that few mine owners have geologists on their staffs. Yet, on modern standards, such detailed geological plans are of equal importance to the ordinary mine plans: whereas the latter are necessary to obtain a clear picture of the mine workings, the former are necessary to obtain an understanding of the deposit and thus to guide future prospecting and development work.

The author must confess that attempts to advise laymen on the preparation of geological plans have been disappointing, except in those cases where the geology was very simple and it was necessary to distinguish between only two or three rock types which were easily recognisable. It would be of little moment what the rocks were called so long as the layman were consistent in his descriptions, but unfortunately for simplicity in mapping rocks have the habit of showing so many variations that consistency becomes difficult except to the geologist. The only reliable advice on this subject that can be given to a mine owner is that he should employ a geologist wherever possible, either permanently on his staff should the property be large enough, or from time to time as developments necessitate.

For surface workings the geological plans should include not only a detailed geological map of the surface, but also, if possible, a series of geological sections at regular intervals in order to indicate what is likely to happen as the deposit is followed in depth. As the surface workings are enlarged and more of the geology becomes clearly exposed, the geological plans should increase in detail; such detail will eventually provide the basis on which the mine workings are extended.

The geological mapping of underground workings is generally a much more precise task than at the surface. It may be necessary to examine and plot carefully the rock variations in every foot of underground workings, not uncommonly under most uncomfortable and difficult conditions. The particular method to be adopted in delineating this detail on paper may, in certain cases, require careful thought. In a small mine with simple geology a geological plan of each level and a few geological transverse sections may suffice. For large mines it may be necessary not only to prepare a geological plan of each level, but also the geology at definite intervals between levels may be plotted as stoping progresses; transverse sections at close intervals may be essential to a proper representation of the detail. On a large underground mine, which employs a staff of geologists to plot constantly the geology in the changing develop-

ment workings and stopes, the geological plans may be assembled into quite an extensive portfolio.

The plans and sections may also be converted into a block diagram constructed on one or other of the various three-dimensional principles that have been described in recent years. These diagrams permit the geology and mine workings to be viewed as a whole so that the relation of one feature to another is more clearly understood.

Actual models of the mine workings may also be constructed. At one time a favourite type of model was constructed of glass sheets on which the levels were painted; it is now common practice to model the ore-body from some moulding material, painted according to the various features. Such models are perhaps the best means of representing to laymen the details of underground mines.

Once it is clearly recognised that geological mine plans not only aid in guiding development work, but also lead to the maximum extraction of mineral in mining and ultimately to the reduction of costs, it is likely that they will be more frequently used in India.

CHAPTER XIII

MINE ACCOUNTS

Fundamentally, the object of mine accounts is to determine the current financial position of the undertaking—whether it is making a profit or a loss. It will obviously be necessary for the accounts to be concerned in greatest detail not with the sales, which represent relatively few transactions, but with the various items of expenditure.

Mine expenditure may be divided into two kinds, capital expenditure and revenue expenditure, the distinction between which is not always clearly defined.

Capital expenditure, apart from such plant and buildings as are not paid for out of earnings, will include mainly the cost of shafts and crosscuts, and such drives, rises and winzes as are necessary to provide the recognised working reserves for the mine. Once these reserves are established, the cost of further drives, rises and winzes to maintain the quantity of reserves should be charged to revenue account.

Revenue expenditure will include the cost of actually mining the mineral produced from the mine, *i.e.* drilling, explosives, timber, trucking, labour, hoisting, pumping, etc., as well as administration charges and general expenses.

Annual statements to shareholders should include—(*a*) the balance sheet, (*b*) the profit and loss account, and (*c*) the reports of the manager and the directors.

The detail which should be provided to the public in the profit and loss account is determined by the policy of the company, but the shareholders are certainly entitled to know the total expenditure of each department in order that they may judge of their efficiency. Certain charges have to spread over a number of departments and an equitable ratio of allocation should be determined.

The report on the mine by the manager should aim at giving the shareholders an accurate picture of the condition of the mine, the amount of its developed reserves, the amount of mineral produced and treated, the amount of development work done, the new construction and equipment purchased during the year, with a technical assessment of the future outlook for the property. The directors' report should concern itself more particularly with the financial position, leaving the manager's report unadorned, but comments are permissible on the relation of that report to market and financial conditions in general.

The above brief comments are on the general accounts which summarise the financial position of the mine as a whole but the keeping of mine accounts should not be the mere recording of transactions involving expenditure and receipts. During the course of operations, from day to day or month to month, an analysis should be made of every operational item and a detailed costing system maintained in such a way that a close check is kept on efficiency throughout. On a large well-organised metal mine, where the staff is constantly on its toes to reduce costs at each stage of the operations, the costing system may be more detailed perhaps than in any other form of business. This probably explains why engineers of long experience have proved such successful economists and administrators of extensive financial operations, for their earlier executive duties have forced them to a close personal appreciation of the significance of every item of costs in varied operations; ultimately the engineer's insight into this aspect of production is necessarily far more thorough than that of the man trained in purely office routine.

In a small mine, employing only a few men and undertaking simple operations, cost-keeping will not involve complex records. It may suffice to keep a record of—

(*a*) Total daily and monthly production.

(*b*) Total labour, divided into machine-men, shovellers, timbermen, and other labour, with wages per day and month, and cost of each per ton of mineral.

(*c*) Power costs, distributed, if possible, between the various operational items.
(*d*) Total feet drilled daily and per machine, and cost per foot and per ton.
(*e*) Explosives, total cost and per ton.
(*f*) Timber, sizes, total cost and per ton.
(*g*) Pumping, total cost and per ton.
(*h*) Hoisting, total cost and per ton.
(*i*) Stores, total cost and per ton.
(*j*) Supervision, total cost and per ton.
(*k*) Administration, total cost and per ton.

In large mines with more extensive operations, perhaps involving also milling and smelting, the records will be more detailed, but the detail should not be taken to such a point that it defeats its own object of conciseness of facts. It is a very useful aid to administration if the more important of the above items are converted into graphs, thus permitting the general trend of each to be seen at a glance. Correctly designed and used, such graphs may provide a ready means of checking the efficiency of labour and the consumption of stores.

On a mine of any size the details of costing are determined, of course, from the daily reports submitted by the supervising staff in charge of the various operations and departments. These reports are in the form of standardised tabular statements in which the details of labour, supplies, production, footage, etc. within each section are concisely stated, so that they can be readily assembled in the accounts department. If in loose-leaf form and carefully designed, these departmental records themselves may make up the cost accountancy and actual book entries within the accounts department may be reduced to a minimum.

It is the practice in many large mining enterprises to issue to the staff in each department monthly records of costs concerning that department. The details are supplied on blue prints showing the average cost of each item for the previous year and for each successive month during the course of the current year. In this

way each member of the staff is in a position to study the variations in his costs and to adjust his operations accordingly. In addition, this tends to promote a spirit of friendly rivalry amongst an efficient staff which is in close cooperation with its labour. For example, the underground workings of a mine may be divided into two or more sections, each under the supervision of an assistant underground manager or mine agent. Each will study his costs—drilling, explosives, shovelling, timber, development, stoping, etc.—and compare them with those for the other mine sections; reasons for unusual features in the respective costs of each section will be discussed, and each section having pride in its technical competence will endeavour to improve its efficiency beyond that of the others.

A well-designed costing system which details the production results of the various stages of operations will also expose the bottle-necks in through-production. For example, a mine may be capable of producing a certain tonnage of mineral but either the mine crusher, or the transport to the mill, or the mill, may not be able to handle that tonnage. Attention will then be paid to improving efficiency at the bottle-neck and this may result in the bottle-neck moving to some other stage in the operations. At one period the mill may be the bottle-neck, at another the mine or the smelter. Thus bottle-necks and relatively inefficient operations are constantly eliminated and the general efficiency of the whole plant raised.

CHAPTER XIV

RELATION BETWEEN TECHNICAL STAFF AND ADMINISTRATION

In most parts of the world the accepted practice, arising out of prolonged experience in mining, is for the controlling administrative staff of mines to be selected from technical men who have spent the earlier years of their careers in various phases of mining. This practice recognises the fundamental necessity of having in control men who are completely familiar with all details of the engineering side of their profession; it relegates to its correct position of comparatively lesser importance the knowledge of pure book-keeping and office routine possessed by the accounting staff and recognises that a knowledge of the economic and financial side of mining is more soundly acquired by the technical men who, throughout their mining experience, have been closely and persistently engaged in keeping down their own costs and in studying through the technical literature the varying aspects of mining throughout the world. It is not the normal practice to have in administrative control of such highly technical engineering operations non-technical men such as accountants or lawyers; any proficient mining engineer can make himself sufficiently acquainted with the necessary accountancy or company law which may be required of him and whenever more complex questions of accounts or law crop up he can obtain the necessary professional advice. It is recognised that technical problems are of daily occurrence, but accountancy and legal problems are only occasional.

In India this advisable practice is not general, notably in the coal industry where the managing agency system has persisted since the commencement of coal mining in India. There is much to be said for the managing agency system as applied to Indian coal mining in which, because of keen competition in marketing, sales organisation is of such great importance. Managing agents, besides

controlling mines, may also control jute, sugar, paper, rice and other mills, and the mines production may be of great importance in providing supplies to other industries within the group controlled by the agency. The system can be particularly successful so long as the managing agents follow definitely the advice tendered to them by their technical staff, not only in the technical working of the mine, but in all policies of development and expenditure relating to the mine's present and future efficiency and life. However, managing agents cannot always be expected to have that long-term outlook which a mining engineer who is efficient must possess; immediate expansion of profits is of greater concern to some managing agents than prolonged future profits, for to them the clamour of the shareholders at the moment is of great significance.

Mining men in India have severely criticised the managing agency system, at times not without cause. It has its uses, especially from the sales point of view, and there would be little objection to the system if sales remained its simple purpose and the administrative control of the mines were left to the mining engineers. It may be of interest to remark that one of the most efficient mining organisations in India at the present day is one in which the administration is in the control of mining engineers of long technical experience and in which sales are made through a managing agency which, however, has no administrative control in the mine's affairs.

What, then, is the most appropriate organisation of administrative and executive staff in a mining concern? No hard and fast list of heads of departments and divisions into sections and sub-sections can be drawn, as mining operations are so variable. For a fairly extensive mining company, the general manager—a man usually of wide mining or metallurgical experience depending upon which side the company's activities are emphasised—should have directly under him the mine manager (or superintendent), mill manager, smelter manager, power superintendent, chief accountant, and chief medical officer. The mine manager will have under him perhaps an assistant mine manager, surveyor, geologist, and underground managers or mine agents who will each be in charge of a section of the mine; the surface plant and shaft may perhaps come

under the supervision of the assistant manager. Under the underground managers are the shift bosses who are each answerable for certain levels and stopes. In some organisations the mill and smelter may be each supervised by a superintendent under a works manager, and the geologist may be answerable only to the general manager. A company with complex operation, such as an iron and steel corporation, may have several more heads of departments than those listed above, with a detailed subdivision of responsibility within each department. On the other hand, in a small mine the manager may be in direct control of all phases of the operations.

It should be possible for the younger technical staff to be able to look forward to gradual future promotion right through to the head of their respective departments and eventually, perhaps, to the position of general manager. But it is not uncommonly advisable for a company's directorate to appoint a man of wide technical experience from outside as general manager—the infusion of fresh ideas at the top is often advantageous. Similarly, young energetic geologists and engineers of broad outlook, keen to expand their experience and thus their general efficiency, are well advised to spend the first 10–12 years of their careers on several widely different types of mines, if possible in various countries. The writer remembers that, when commencing his career on a group of gold mines in Australia, he was advised by an older mining engineer to stay no longer than three years on any one type of mine for a period of twelve years.

The relation between the general manager and the directors of the company needs little discussion. The general manager is appointed to his position by the directors and the latter should trust in the technical and administrative ability of the man of their choice. The directors are responsible to the shareholders for the broad policy of the company as a whole and this, naturally, will include any technical items requiring considerable expenditure. They should avoid undue interference in the details of operation which may cause friction, as this crosses the field of the general manager whose technical actions must be accepted—no efficient general manager of wide experience is likely to accept continuous

interference in his plans by laymen. For this reason it is advisable for any mining company to include on its board of directors one or two mining engineers of experience.

The above views of the author, that mining operations are best administered by men of wide technical training and experience, may be subject to criticism. In the oil industry, administration practice has been on different lines, with a tendency to specialise the administrative side or connect it more particularly with sales; but it has been found increasingly advantageous of recent years to appoint technical men, including geologists, to administrative posts, even as general managers or managing directors of oil companies. For a time, particularly in America, it was thought that a training in economics and business administration was the best background for appointments to administrative posts, but there has very recently been a reversion to the older and more persistent view that detailed technical experience, during which knowledge of economics and business methods is accumulated, provides the best background for the prospective administrator.

CHAPTER XV

MINE WELFARE

An important and in some cases costly item in mining in India, as in any country, is the welfare of the employees. Apart from the coalfields and certain large iron and steel, copper and manganese concerns, welfare has not been given that attention which it deserves; however, it is pleasing to note that in some of the very largest companies the employees have been given a measure of welfare attention comparable with that in America and Australia.

Practically all of the larger mines in India must make their own arrangements for housing both staff and employees. This may be a very heavy item in capital cost and due allowance must be made for it in the original capital estimates. A comfortably housed staff and labour means contented employees. In many cases because of the relative transience of mining staff furnishing of their quarters must also be accepted by the company. For large mines and treatment plants whole townships may be constructed, with paved streets and electric lighting.

For the large number of smaller mines scattered throughout India, however, the labour is either gleaned from the local villages, or if because of inaccessibility labour has to be kept near the mines, only the most primitive arrangements are made, commonly merely leaf shelters are erected.

Some companies, to save themselves the expense and trouble of keeping labour close to the mines, may transport the miners daily by bus from the villages to the mines.

It is true that in the early stages of a mine it may be inadvisable to make any considerable expenditure on housing. But, even on the smaller mines, once they are established and with every prospect of some relative permanence, at least some part of the annual gross profits should be devoted to the improvement of miners' amenities.

Provision for adequate water supply on mines must be made in accordance with the Mines Act. This provision is wisely extended to the whole mining camp or town in the case of larger mines and treatment works. With it must be associated measures for water purification, as neglect of this may lead to epidemics. As in the case of adequate housing and medical attention, a plentiful supply of drinking and washing water is as much in the interests of the employer as the employee, for it helps to ensure a continual supply of healthy labour.

Although medical attention is recognised by the larger companies in India as of vital importance in mining, and well-equipped hospitals have been erected by most of them, this side of welfare is utterly lacking in many of the smaller mines scattered throughout the country. One cannot, in some cases, blame the employers, they are unable to support the necessary expense and must leave medical attention to the district medical officers or local charitable hospitals. In malarious districts, particularly, medical costs on mines may be very high indeed because of the expensive malaria control measures which must be continually adopted throughout the vicinity of the mine area. Not uncommonly a mine dispensary finds that it is advisable to supply medicines not only to the mine employees, but also to villagers within a wide radius of the mine.

Sanitation in mines comes within the provisions of the Mines Act, but even so, during visits to many of the smaller mines the author could have wished that greater attention were paid to this very necessary health requirement. From the point of view of their importance in preventing disease and epidemics alone, careful sanitary measures in both mine and mine camp are in the interests of the employer, and he should insist that mine labour should consistently observe clean sanitary practices. Most of the large companies give an attention to sanitation which is creditable.

In some areas welfare attention may extend to the establishment of schools for the miners' children. This not only encourages labour to remain on the mine, but also leads, after a period of years, to a better educated labour becoming available as the miners' children grow up. Night schools for the miners themselves may also be

advisable in order to train the more capable of the skilled labour to take on more responsible positions, such as foremen, mine sardars or shot firers.

The necessity for attention to all of these factors in labour welfare is gradually being accepted throughout India and the miners' lot is improving; indeed, the living conditions of labour on many of the larger mines are equal to those in the best planned communities in India.

CHAPTER XVI

VALUATION AND INVESTMENT FORMULAE

The value of a mineral deposit to an investor will depend upon the likely profit to be obtained from it and upon a comparison of this profit with the ruling market rates of interest obtainable for the use of capital. Estimates of the likely profit will be governed by several variables which are discussed in chapter XVII, but, from the point of view of the mining investor, the profit obtained in mining must be regarded in the same way as interest rates in other forms of investment, making due allowance for the more speculative nature of many mining ventures.

A mineral deposit in process of being mined is a depleting asset, that is to say, it contains limited reserves which, at a definite rate of extraction, will be reduced to zero within a certain number of years. The investor expects, therefore, that during the life of the property he will obtain not only a fair interest on the capital invested but ultimately, in addition, a full return of his capital. In other words, the annual return from his investment will consist of two parts: (*a*) a speculative rate of interest increasing with the risk involved, and (*b*) an additional amount which, if placed to a reserve fund at a safe rate of interest, will, on expiry of the property, equal the original capital invested.

It is apparent that we are here dealing with the effects of compound interest on the varying value of money. These effects can be reduced to certain mathematical formulae which can best be traced in stages with the aid of simple examples.

The following notation will be used:—

P = principal, also capital.

i = rate of interest. Various rates may be designated i', i'', i''', etc.

I = amount of Re1 plus one year's interest $= 1+i$.

T = total interest.

S = total accumulated amount.
n = any complete number of years.
m = any complete number of years distinguished from n.
t = number of times interest may be paid in one year.
C = cash or present value of an amount due in the future. May also represent capital.
a = any form of annuity, designated more specifically by profit—p, dividend—d, and sinking fund payment—f.
A = total accumulated annuity at i rate of interest; total sinking fund—F.
R_n = total amount to which an annuity of Re1 will accumulate at i rate of interest in n years.

Compound interest accumulation

Now, $I = 1+i$

In n years, $I^n = (1+i)^n$ .. .. .. (i)

and for any sum, $PI^n = P(1+i)^n = S$ .. .. (ii)

Also $T = S-P$

$T = PI^n - P = P(I^n - 1)$ .. .. (iii)

The values $(1+i)^n$ for various rates of interest are given in Table 13.

Example 8.—What will Rs500 be worth in 12 years at 4% compound interest?

$$S = P(1+i)^n = 500(1+\cdot 04)^{12}$$
$$= 500(1\cdot 6010) \quad \text{from Table 13}$$
$$= \text{Rs}800\text{-}8\text{-}0$$

Example 9.—What will be the interest earned on Rs500 in 12 years at 4%?

$$T = P(I^n - 1) = 500(1\cdot 04^{12} - 1)$$
$$= 500(1\cdot 601 - 1) = \text{Rs}300\text{-}8\text{-}0$$

Cash, or present value, of an amount due in n years

As above, a sum P after n years at i rate of interest will accumulate to $P(1+i)^n$. The reverse of this is now required, that is, the amount C which, in n years at i rate of interest, will equal P.

The simplest case is when $P = \text{Re}1$.

$$\text{Then } CI^n = 1 \text{ or } C = \frac{1}{I^n} \quad \ldots \quad \ldots \quad \text{(iv)}$$

Hence the cash or present value of Re1 due in n years at i rate of interest is the reciprocal of the sum to which Re1 would accumulate in n years at i rate.

$$\text{Also, for any sum, } C = \frac{P}{I^n} \quad \ldots \quad \ldots \quad \text{(v)}$$

The values, $\frac{1}{I^n}$, for various rates of interest are given in Table 14.

Example 10.—It is desired, in 10 years, to accumulate a sum of Rs10,000. What amount must be deposited now, if the interest rate is 4%?

$$C = \frac{10{,}000}{(1{\cdot}04)^{10}}$$
$$= \text{Rs}6{,}756$$

ANNUITY ACCUMULATION

An annuity is a fixed amount payable at regular intervals, usually annually. An 'immediate annuity' is one payable at the end of each year; an 'annuity due' is one payable at the beginning of each year. An annuity may be permitted to accumulate at a fixed rate of compound interest. The case of 'immediate annuities' will be considered.

The annuity or amount paid at the end of the first year is a, and, if this is left to bear interest, at the end of the second year it will be worth $aI^{(2-1)}$, whilst after n years this first year's annuity will be worth $aI^{(n-1)}$. Hence the sum of the annuities for each successive year, or the accumulated annuities, will be:

$$A = aI^{(n-1)} + aI^{(n-2)} + aI^{(n-3)} \ldots\ldots\ldots\ldots aI^2 + aI + a$$

and $$IA = aI^n + aI^{(n-1)} + aI^{(n-2)} \ldots\ldots\ldots\ldots aI^3 + aI^2 + aI$$

$$\text{then} \quad IA - A = aI^n - a$$
$$A(I-1) = a(I^n - 1)$$
$$A = \frac{a(I^n-1)}{I-1}$$
$$= \frac{a(I^n-1)}{i} \quad \ldots \quad \ldots \quad \text{(vi)}$$

When $a =$ Re1, in n years at i rate of interest, the accumulated amount R_n of Re1 will be

$$R_n = \frac{I^n - 1}{i} \quad \ldots \quad \ldots \text{(vii)}$$

$$\text{and} \quad A = aR_n \quad \ldots \quad \ldots \text{(viii)}$$

The values of R_n or $\frac{I^n - 1}{i}$ for various rates of interest are given in Table 15.

Example 11.—A mining company decides to set aside Rs20,000 per year for a period of 10 years to purchase a new property when its present mineral deposit will be depleted. If the amount is invested at the prevailing safe rate of 4%, what will be the accumulated amount?

$$F = \frac{f(I^n - 1)}{i} = \frac{20{,}000(1{\cdot}04^{10} - 1)}{{\cdot}04}$$
$$= 20{,}000(12{\cdot}0061) \quad \text{from Table 15}$$
$$= \text{Rs}240{,}122$$

CASH OR PRESENT VALUE OF AN ANNUITY

The present value of an annuity to be paid for n years may be regarded as made up of a series of amounts, each representing the present value of the annuity to be paid at the end of each successive future year.

$$C = \frac{a}{I} + \frac{a}{I^2} + \frac{a}{I^3} \ldots\ldots\ldots + \frac{a}{I^{(n-2)}} + \frac{a}{I^{(n-1)}} + \frac{a}{I^n} \quad \text{(see v)},$$
$$= \frac{aI^{(n-1)} + aI^{(n-2)} \ldots\ldots\ldots\ldots aI + a}{I^n}.$$

Now

$$A = aI^{(n-1)} + aI^{(n-2)} \ldots\ldots\ldots\ldots aI + a = \frac{a(I^n - 1)}{i} \quad \text{(see vi)}.$$

$$\text{Hence} \quad C = \frac{\frac{a(I^n - 1)}{i}}{I^n} = \frac{a(I^n - 1)}{I^n i} \quad \ldots \quad \ldots \text{(ix)}$$

$$\text{Also, when} \quad a = \text{Re1}, \quad C = \frac{I^n - 1}{I^n i} \quad \ldots \quad \ldots \text{(x)}$$

The values of $\frac{I^n - 1}{I^n i}$ for various rates of interest are given in Table 16.

Example 12.—A mine is sold for Rs150,000, to be paid in equal amounts of Rs10,000 per year for 15 years. The current safe rate for money is 5%. What is the equivalent cash value to the seller?

$$C = \frac{a(I^n - 1)}{I^n i} = \frac{10{,}000(1{\cdot}05^{15} - 1)}{1{\cdot}05^{15} \times {\cdot}05}$$

or

$$= 10{,}000 \times 10{\cdot}3797 \quad \text{from Table 16}$$
$$= \text{Rs}103{,}797$$

Example 13.—A limestone property with 50 lakhs tons of limestone reserves is sold for Re1 lakh cash plus Rs15,000 per year for 20 years. What is the present value of the limestone reserves per ton, assuming the speculative interest rate is 5%?

$$C = \frac{a(I^n - 1)}{I^n i} = \frac{15{,}000(1{\cdot}05^{20} - 1)}{1{\cdot}05^{20} \times {\cdot}05}$$
$$= \text{Rs}186{,}933$$

Rs100,000 cash paid

Rs286,933 total present value.

$$\text{Value per ton} = \frac{286{,}933}{5{,}000{,}000} = 0{\cdot}9 \text{ annas per ton.}$$

Adjustment of formulae when interest is paid at fractional intervals

If the interest is payable t times in one year, this is equivalent to reducing the interest to $\frac{i}{t}$ payable t times, so that I becomes $\left(1+\frac{i}{t}\right)^t$. In n years it will be payable tn times. Hence, in the preceding formulae, if $\left(1+\frac{i}{t}\right)^t$ and tn are substituted for I and n respectively, the requisite formulae are obtained for the new conditions. Where i occurs in the original formula it must be

substituted by $I-1$ and I converted to $\left(1+\frac{i}{t}\right)^t$; thus i becomes $\left(1+\frac{i}{t}\right)^t-1$.

The respective equations now become:

$$\text{For (ii)} \quad S = P\left(1+\frac{i}{t}\right)^{tn}$$

$$\text{For (iv)} \quad C = \frac{1}{\left(1+\frac{i}{t}\right)^{tn}}$$

$$\text{For (v)} \quad C = \frac{P}{\left(1+\frac{i}{t}\right)^{tn}}$$

$$\text{For (vi)} \quad A = \frac{a\left[\left(1+\frac{i}{t}\right)^{tn}-1\right]}{\left(1+\frac{i}{t}\right)^{t}-1}$$

$$\text{For (ix)} \quad C = \frac{a\left[\left(1+\frac{i}{t}\right)^{tn}-1\right]}{\left(1+\frac{i}{t}\right)^{tn}\left[\left(1+\frac{i}{t}\right)^{t}-1\right]}$$

Redemption or Amortisation of Capital

It has already been remarked that, as a mine's profits are paid from the production of a depleting asset, the investor must regard part of those profits as a return of capital. In some cases a company may actually accumulate a redemption fund to perpetuate its activities in other properties when its present mine is exhausted. A fund may also be accumulated to take care of depreciation of plant or for other purposes. The annual amount f set aside for the accumulation of such sinking funds F represents an annuity.

$$\text{Now} \quad F = \frac{f(I^n-1)}{i} \quad \text{(see vi)}$$

$$\text{thus} \quad f = \frac{Fi}{(I^n - 1)} \quad \ldots \quad \ldots \quad \ldots \quad \text{(xi)}$$

$$\text{or, when } F = \text{Re1}, \quad f = \frac{i}{(I^n - 1)} \quad \ldots \quad \ldots \quad \ldots \quad \text{(xii)}$$

Example 14.—A mine possesses plant worth Rs2 lakhs which, it is estimated, will require renewal in 15 years. What annual payments must be made to a sinking fund, at 5%, to replace the plant?

$$f = \frac{200{,}000 \times \cdot 05}{1{\cdot}05^{15} - 1}$$

or

$$= \frac{200{,}000}{21{\cdot}5786} \quad \text{from Table 15}$$

$$= \text{Rs}9{,}268$$

DIMINISHING ANNUITIES

Instead of building up a sinking fund to purchase plant, a reverse method may be adopted: the money to purchase plant may be borrowed and each year a certain portion of the principal may be paid off, plus interest on the balance due for that year. The annual sum allotted for this purpose may remain constant, in which case the proportion paid towards extinction of the principal will increase progressively, the interest decreasing. If P is the original principal or total fund borrowed, and f the annual payments, then the principal will diminish as follows:

$PI - f$ .. .. .. at the end of the first year.
$(PI - f)\,I - f$ .. .. at the end of the second year.
$(PI^2 - fI - f)\,I - f$ .. at the end of the third year.
$PI^n - fI^{(n-1)} - fI^{(n-2)} \ldots\ldots - fI^2 - fI - f$ .. .. for n years.

For the principal to diminish to zero, then

$$PI^n - (fI^{(n-1)} + fI^{(n-2)} \ldots\ldots\ldots\ldots + fI^2 + fI + f) = 0,$$

i.e.

$$PI^n - \frac{f(I^n - 1)}{i} = 0 \quad \text{(see derivation of vi)},$$

$$PI^n i = f(I^n - 1),$$

$$I^n = \frac{f}{f - Pi}.$$

So that the number of years necessary to pay off the principal will be

$$n = \log\left(\frac{f}{f-Pi}\right) \div \log I \quad .. \qquad .. \text{(xiii)}$$

Example 15.—For the purchase of a new crusher and generator plant, a company borrows Rs80,000 at 7%, which it proposes to pay back at the rate of Rs10,000 per year. How long will it take?

$$n = \log\frac{10{,}000}{10{,}000-80{,}000\times\cdot 07} \div \log 1{\cdot}07$$
$$= \log\frac{10{,}000}{4{,}400} \div \log 1{\cdot}07$$
$$= \frac{\log 2{\cdot}3}{\log 1{\cdot}07}$$
$$= 13 \text{ years}$$

Present or cash value of a redemption annuity, Hoskold's mine valuation formula

Formula (vi) enables us to calculate the ultimate value of an annual payment accumulating at a certain rate of interest. Formula (xi) enables us to calculate the amount necessary to set aside annually, at a certain rate of interest, in order to accumulate a definite sum in a certain number of years. These two formulae may be adapted to the peculiar conditions of mining investment.

It has already been remarked that the mining investor expects to recover his original capital investment during the life of the mine, hence a mining dividend may be considered to consist of two payments: (*a*) the amount which the investor expects as interest on his speculative investment, and (*b*) the amount necessary to set aside, at a safe rate of interest, for the ultimate recovery of the original capital.

During the life of a mine the total earnings would be equivalent to a sum which represents the ultimate value of the property. That ultimate value can be realised only after a certain number of years (the property's life), so that the present or cash value will be only a fraction of this—this present value is determined as follows:

If i' = the speculative rate of interest on the investment.

i = the current safe rate of interest on the redemption fund.

$R_n = \frac{I^n-1}{i}$ = the accumulated value of Re1 in n years at i, the safe interest rate on the redemption fund.

d = dividend.

Also C and P are synonymous, for the present value may be regarded as equivalent to the capital value.

Then $d-Ci'$ = the annual redemption of capital.

$(d-Ci')R_n$ = the total redemption fund $= C$, as the total redemption fund has to equal the original capital investment, or present value of the property.

Hence

$$C = dR_n - CR_ni'$$

$$C(1+R_ni') = dR_n$$

$$C = \frac{dR_n}{1+R_ni'}$$

$$= \frac{d}{\frac{1}{R_n}+i'}$$

$$\text{or} \quad C = \frac{d}{\frac{i}{I^n-1}+i'} \quad \ldots \quad \ldots \quad \text{(xiv)}$$

This may also be written

$$C = d\frac{(1+i)^n-1}{(1+i)^n i' - i' + i}.$$

Formula (xiv) was first derived in 1877 by Hoskold and is commonly known as the Hoskold formula. It is used for calculating the value of mineral properties.

If d = Re1 per year, then

$$C = \frac{1}{\frac{i}{I^n-1}+i'} \quad \ldots \quad \ldots \quad \text{(xv)}$$

The values of C in equation (xv) for various rates of speculative and redemption interest are given in Table 17.

It will be observed that part of the denominator in the above formula is represented by formula (xii), $f = \frac{i}{(I^n - 1)}$, where f is the annual payment which, in n years at i percent, will amount to Re1. Hence Hoskold's formula may also be written:

$$C = \frac{d}{f + i'} \qquad \ldots \qquad \ldots \text{ (xvi)}$$

Or again, it may be written

$$C = \frac{d}{\frac{1}{R_n} + i'} \qquad \ldots \qquad \ldots \text{ (xvii)}$$

Example 16.—A manganese mine has been showing profits of Rs50,000 per year for several years and at the present rate of working is expected to last 10 years. A prospective purchaser desires 10% on his investment, with return of capital, the safe interest being taken at 4%. What is the property worth to him?

$$C = \frac{50{,}000}{\frac{\cdot 04}{1{\cdot}04^{10} - 1} + \cdot 10}$$

or

$$C = 50{,}000 \times 5{\cdot}4558 \quad \text{from Table 17}$$
$$= \text{Rs}272{,}790$$

Example 17.—A quarry is equipped to produce 50,000 tons of ballast per year, at a profit of 8 annas per ton. The total tonnage available is estimated at 2,500,000 tons. With a speculative interest rate of 7%, and a safe interest rate of 4%, what is the cash value of the deposit?

$$d = 50{,}000 \times \cdot 5 = \text{Rs}25{,}000$$

$$n = \frac{2{,}500{,}000}{50{,}000} = 50 \text{ years}$$

$$C = \frac{25{,}000}{\frac{\cdot 04}{1{\cdot}04^{50} - 1} + \cdot 07}$$
$$= \text{Rs}326{,}582$$

Example 18.—A limestone deposit, with reserves of 5 million tons, is expected to be worked at the rate of 100,000 tons per annum, at a profit of Re1 per ton. With speculative interest rate at 10%, and the safe rate on capital redemption 4%, what is the limestone worth per ton?

$$C = \frac{100{,}000}{\frac{\cdot 04}{1\cdot 04^{50}-1}+\cdot 10}$$
$$= \text{Rs}938{,}520$$
$$= 3 \text{ annas per ton.}$$

ALTERNATIVES TO THE HOSKOLD FORMULA

The premise upon which the Hoskold formula is based is that the dividend is definitely divided into two fixed amounts which do not vary annually—(*a*) the amount due according to the speculative interest rate, and (*b*) the 'dividend overplus' or amount necessary for ultimate capital redemption. Although this principle of the division of the dividend into two parts is generally acknowledged, there has been some difference of opinion as to whether the proportions of these parts should remain constant. It has been contended that, as the amount of capital invested is being reduced annually by amounts equivalent to the sinking fund, the amount due from the speculative rate should be progressively smaller. In other words, the annual amount allotted from the dividend for capital redemption should progressively increase, and the amount allotted to speculative return should decrease. In 1918, Whitton [1] suggested this principle, but at the same time accepted Hoskold's view that the redemption fund should accumulate at compound interest. He thus obtained the following formula:—

$$C = d\frac{(1+i+i')^n-1}{(1+i+i')^n i'+i} \quad \ldots \quad \ldots \text{(xviii)}$$

Morkill,[2] in 1918, criticised the principle of permitting compound interest on the redemption fund to enter into the calculation, as

[1] W. W. Whitton, 'Mine valuation', *Min. and Sci. Press*, May 18, 1918.

[2] D. B. Morkill, 'Formulae for mine valuation', *Min. and Sci. Press*, p. 276, Aug. 31, 1918.

by so doing 'the investor places himself in the position of having the whole amount of the original investment tied up while drawing interest on a continually decreasing portion'. He assumes 'that the investor, while drawing risk rate interest on the amount of capital remaining in the original venture, is also entitled to security rate interest on the portion that is considered to be returned, for it necessarily does not come into his use if it must be set aside as a sinking fund'. Hence, only the risk rate enters into his valuation. Morkill's formula [1] is as follows:—

$$C = d\frac{(1+i')^n - 1}{(1+i')^n i'} \qquad \ldots \qquad \ldots \qquad \text{(xix)}$$

As is to be expected, this formula is of the same type as that given in formula (ix) for the present value of an annuity at a single rate of interest.

Grimes and Craigue introduced yet a further refinement to Whitton's construction. Not only is the sinking fund considered as accumulating at a safe rate of interest, but also the investor 'is paid a semi-speculative rate of interest—a rate of interest intermediate between the speculative and safe rates—upon the amount of capital in the sinking fund at the beginning of each year'. The reason for this semi-speculative rate is 'the possible diversion of the sinking fund to other purposes than return of capital', justifying 'a demand for a rate of interest higher than the safe rate, but less than the speculative rate upon unreturned capital'.[2] If i'' designates this semi-speculative rate the formula they derive is:

$$C = d\frac{(1+i'-i''+i)^n - 1}{(1+i'-i''+i)^n i' - i'' + i} \qquad \ldots \qquad \text{(xx)}$$

All of these formulae may be subject to criticism according to whether they do or do not take into account some aspect of the

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[1] The formula quoted in Morkill's paper is:

$$C = d\frac{(1+i')^n - 1}{(1+i')^n - i'}$$

which is obviously a typographical error.

[2] Grimes and Craigue, 'Principles of valuation', p. 46, Prentice-Hall Inc., 1928.

method of return of capital favoured by the individual. A comparison of the formulae shows that Hoskold's gives the most conservative or lowest estimate of the present value. In a speculative investment of this nature it is obvious, therefore, that the Hoskold formula errs, if at all, on the safe side for the buyer. Probably, for this reason also, it is the formula most widely used by mining engineers and is accordingly recommended here.

Requisite earning life of a mining investment

The number of years life of a mine will be determined by the rate per annum at which the reserves are depleted. To the investor it is necessary that the expected dividend rate will suffice to provide the desired speculative interest rate and will also permit the return of capital during the life of the mine. On the Hoskold conception of the redemption of capital, the annual percentage return of capital is the difference between the dividend and speculative interest rates, *i.e.*, the dividend overplus. This dividend overplus may be regarded as an annuity accumulating at the safe interest rate i, and the problem is to determine the number of years in which this annuity will equal the original capital.

In terms of percentages, it is desired to accumulate the percentage difference between dividend d and speculative interest rate i', *i.e.*, f written as a percentage, at i rate of interest until it amounts to 100% (or, in the previous formulae, unity).

$$\text{Now} \quad F = \frac{f(I^n - 1)}{i} \quad \text{(see vi)}$$

$$\text{or} \quad 1 = \frac{f(I^n - 1)}{i}$$

$$I^n = \frac{i}{f} + 1$$

$$n = \frac{\log\left(\frac{i}{f} + 1\right)}{\log I} \quad \ldots \quad \ldots \quad \text{(xxi)}$$

Examples of the use of this formula are given in chapter XVIII.

Table 18 gives the number of years of life required for the dividend overplus, expressed as a percentage of the capital, to accumulate at safe interest rates to 100%.

Present value of a deferred redemption annuity

Sometimes an annuity may not become payable for some years after purchase; for example, it may be known that commencement of dividend payments may not be expected from a mine for a definite period after purchase. If m = the number of years deferment, i'' = the rate of interest allowed on capital during the deferment period, and C_d = value of the annuity at the beginning of its earning period, then the present value C of such a property may be calculated as follows:

$$C_d = \frac{d}{\frac{i}{I^n - 1} + i'} = \frac{d}{f + i'}$$

$$\text{and} \quad C = \frac{C_d}{(1+i'')^m}$$

$$= \frac{\frac{d}{f+i'}}{(1+i'')^m}$$

$$= \frac{\frac{d}{\frac{i}{I^n-1}+i'}}{(1+i'')^m} \qquad \ldots \qquad \ldots \qquad \text{(xxii)}$$

Example 19.—A mine is purchased during a period of depression. It is estimated that production can start 3 years from the date of purchase, and that with an output sufficient to give a profit of Re1 lakh per year its working life will be 20 years. The speculative rate desired is 10%, the interest for the deferment period is 6%, and the safe rate is 4%. What is the present value of the property?

$$C=\frac{\dfrac{100{,}000}{\dfrac{\cdot 04}{1\cdot 04^{20}-1}+\cdot 1}}{1\cdot 06^3}=\frac{748{,}610}{1\cdot 06^3}$$

$$=\text{Rs}628{,}550$$

As O'Donahue[1] has pointed out, formula (xxii) gives a very low present value in those cases where the deferred period is lengthy, and where high interest rates are required during the deferred period. Accordingly, O'Donahue assumed that the speculative rate i' should be permitted on the capital during the entire period (annuity life plus deferred period), but at the same time assumed that the annual returns from this speculative rate accumulate at the safe rate i both during the deferred period and the annuity period; the annuity is also assumed to accumulate at the safe rate. On these assumptions:

$$C+Ci'\left(\frac{I^{n+m}-1}{i}\right)=d\,\frac{I^n-1}{i}$$

$$\text{or}\qquad C=\frac{\dfrac{d(I^n-1)}{i}}{1+i'\left(\dfrac{I^{n+m}-1}{i}\right)}\quad\cdots\quad\cdots\quad \text{(xxiii)}$$

O'Donahue's formula will give a higher present value than Hoskold's deferment formula, particularly for lengthy deferred periods.

Valuation of unequal income to produce uniform dividends

On the basis of Hoskold's formula, Baxter and Parks[2] have provided a formula whereby it is possible to calculate the present value of a varying profit from which a uniform dividend is paid.

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[1] T. A. O'Donahue, 'The valuation of mineral properties', *Trans. Inst. Min. Eng.*, vol. 32, p. 399; and 'Notes on the valuation of mineral properties', *Trans. Inst. Min. Eng.*, vol. 43, p. 32.

[2] Baxter and Parks, 'Mine examination and valuation', Michigan, 2nd edition, 1939, p. 201.

Using the following notation:

n = total life of payments.

m = number of years prior to any given payment.

i = safe rate of interest.

i' = speculative rate of interest.

i'' = rate on borrowed money.

p_m = profit for each year from 1st–mth–nth.

Then the present value of each of the annual profits will be:

$$C = \frac{p_m}{i'\left(\frac{I''^m - 1}{i''}\right) + i'\left(\frac{I''^{n-m} - 1}{I''^{n-m} i''}\right) + \frac{1}{I^{n-m}}} \quad \text{.. (xxiv)}$$

The sum of these will be the total present value, or the capital to be invested in order to give a uniform speculative interest rate i'. The present value will be greater when the profit is decreasing than when it is increasing in successive years. It will be intermediate when the profit is odd or when it is uniform—in the last case it may be calculated by the simple Hoskold formula.

This formula of Baxter and Parks is applicable to particular cases in which the profits, etc., can be estimated exactly. In view of the fact that estimates are normally only approximate such refinements would generally be unnecessary and it would suffice to determine the present value from the estimate of average profits over the period.

CHAPTER XVII

MINE VALUATION

Variables involved

The Hoskold valuation formula comprises three factors: the two interest rates and the profit. The two interest rates are more or less dependent on ruling market rates, although the speculative rate chosen will be partly determined by the experience of the investor. The third factor, probable profit, is obviously difficult to estimate as it is dependent on so many variables. The principal variables are: rate of depreciation and amortisation of capital, reserves and grade of mineral, rate of production, labour costs, cost of materials, transport charges, variation in sale price, and variation in price as compared with the general variation in the commodity index price.

The longer established is the mine and the more settled the local conditions the more accurately can the variables be estimated; indeed, conditions may be so stable that it may be possible to estimate the profits of some mines even more accurately than those of some secondary industries. In some cases reserves of a mineral held within the mining lease may be so great that for all practical purposes the mining investment may be treated as a perpetuity and the speculative interest rate may be little above the safe interest rate. For example, certain iron and steel industries are not uncommonly based on reserves which will give a positive life of at least 100 years.

The younger the life of a mine, particularly in an area in which the industry has only recently been established, the less certain do the estimates become and the more closely do they depend upon the experience of the valuer. It cannot be too strongly emphasised, therefore, how advisable it is for the layman to rely upon the

valuation of a property by a competent mining engineer of long experience.

Interest rates

The amount of interest demanded for the use of capital is an index of the risk attached to that use. No investment can be regarded as completely safe, but certain Government securities and municipal and similar loans may be taken, for practical purposes, as approaching the ideal of safety. Between such safe investments and certain pure speculations there may be all degrees of risk, for which the investor hopes his capital will obtain commensurately greater interest returns.

The safest investments are Government loans. In India, in the past, these have provided an interest return of up to 5% but in very recent years the rate has ranged between 3 and 3½%. Whether there will be a return to past periods of dear money can scarcely be foretold but the prevailing attitude appears to be that a return to past high rates cannot be expected. Accordingly, present anticipations of future income, based on safe investments of the Government security type, should not be based upon a general average rate greater than 3-3½%.

For the use of money on deposit, banks are unable to pay this Government security rate, as the cost of the bank's administration, etc., must be taken into account. On the other hand, the rate at which money can be loaned by the banks for conservative securities must, for the same reason of bank administration and other costs, be at a somewhat higher rate than the current interest on Government securities. The bank deposit rate is thus between 1½-2%, whilst the average bank loan rate may be expected to range between 3½ and 5%.

It is this latter rate which the investor should expect as a minimum from normal industrial investments of the conservative type. Over and above this minimum the investor will expect an additional return according to his estimate of the risk involved.

In mining, the speculative rate of interest will vary according to the type of deposit, the nature of the reserves (whether positive

TABLE 8.

Expected interest rates on various deposits.

	On new deposits.	On established mines paying dividends.
	Percent.	Percent.
Asbestos	15–25	15
Barite	10–15	6–8
Bauxite	10–15	6
Building materials—		
Ballast	10	6–8
Building stone	10	8
Road metal	10	6–8
Sand	10	6–8
Slate	10	6–7
China clay	15–25	8
Chromite	15–20	10–15
Coal	12–15	5–7
Copper	15–20	8–10
Fireclay	15	5–7
Graphite	20–25	20
Gold	15–20	8–10
Iron ore	10	5–6
Kyanite [1]	8	6
Lead-zinc-silver	15	7–9
Limestone	10	5–7
Manganese	10–20	6–10
Mica	15	15
Magnesite	10–20	8
Petroleum	[2]	7

[1] The rates according to the risk involved have been quoted. Actually there is practically no risk, a kyanite deposit is almost a 'gift'; only a minimum working capital is required and actual profits run into hundreds percent.

[2] The risks attendant on exploring new areas are so enormous that the oil speculator is entitled to as great a return on his capital as luck provides. But the purchase of shares in an established oil area is a reasonable enough investment.

or probable), the prospective life of the mine, the probable fluctuations in market prices, the hazards of labour strikes, accidents, collapses, underground fires, etc. But, eliminating those risks

attendant on most industries, the one outstanding risk which distinguishes many mines from other industries is the uncertainty regarding reserves of raw material. To this risk the wide fluctuations of prices of minerals compared with most commodities and the hazards attendant on mining underground are secondary. If the mineral reserves are known for certain, a mining investment is little more speculative than the majority of industrial investments. The speculative rate may be regarded, therefore, as being made up of two parts: the risk rate for the particular type of deposit, and an additional hazard for the particular mine.

In Table 8 are given the author's estimates of the risk rates which may be applicable to various types of mineral deposits in India, as compared with a safe interest rate of 3-3½%. It must be emphasised that these rates will vary with individual mines. For example, a well-developed manganese mine in the Central Provinces with large reserves and with long established market connections is much less of a risk than a small manganese mine in an inaccessible part of the Eastern States. Likewise, the risk attached to a small iron ore deposit mined merely for export is large compared with that attached to a great iron and steel concern. The interest rates are given in two columns, one group is for new mines in the early development stages, the other is for established mines paying dividends. The latter rates are for the use of investors interested in the market prices of shares in dividend-paying mines.

Amortisation and depreciation

In most forms of business, such as in railways, steamship companies, sugar mills and jute mills, provided allowance is made in the accounts for the maintenance of plant, etc., the total profit can be distributed to the investors as interest on their capital. In mining, part of the annual profit must be regarded as return of capital: the annual amounts so considered must be such that if invested at the ruling rate for safe investments they will total the original capital when the mine is exhausted. The term 'amortisation' is applied specifically here to this method of redemption.

Amortisation of capital enters into the valuation of a mine as a hazard only in so far as it is dependent on the life of the mineral reserves, the annual dividend, and the speculative interest rate demanded. As the two rates of interest may be regarded as fixed, the problem is to determine what life is necessary for the investment to secure the ultimate return of capital, using formula (xxi), or alternatively, when the life is known, what annual rate of dividend must be expected to return capital, using Hoskold's formula.

Depreciation, although it literally means 'loss of value', refers to the cost of preventing loss of value, and includes current construction costs to keep plant in good order; in mining it could also include further expenditure on new development, such as new shafts required to reach extensions of the ore-body when old shafts go out of use. Money spent in this way is not an *addition* to capacity or earning power, and is therefore not truly a capital expenditure. But money spent on development or plant which gives a considerable increment to capacity should rightly be regarded as a capital expenditure. Depreciation charges will vary widely according to the type of mine and the type of plant; they will also depend upon improvements of technique and efficiency of plant and processes. Some plants may be out of date within a few years as a result of improvements in processes.

Reserves and life hazards

The methods of calculating the reserves in a mineral deposit have been outlined in chapter VII. In certain cases, as in iron ore or coal mines, the total reserves may be determinable before mining is actually commenced. At the other extreme, as in china clay or asbestos mining, there may be no attempt to establish reserves. Between these extremes there are all cases in some of which the blocked out or proved ore is a maximum, and probable and possible ore a minimum, whilst in others the proved ore is a minimum and the probable and possible ore must remain a maximum during the life of the mine. In many deposits it is economically not prudent to prove more than two or three years' supply of ore at any one time;

to develop more ore reserves would lock up so much money in development that such a procedure would become financially unjustifiable, and indeed might result in a financially unsound position.

The allowance which should be made for probable and possible reserves in the valuation of a mine must depend upon the skill and experience of the geologist or mining engineer. It is not at all uncommon for the layman to assume vast possible reserves on the evidence of only a few tons of positive reserves. Recently the writer had difficulty in persuading the promoters of a small gold venture, the positive reserves of which were little more than 100 tons of ore, from raising capital to install plant for the immediate treatment of 500 tons per day! It was obvious that, whilst development was proceeding during the next few years, a plant capable of dealing with 15 to 20 tons per day would suffice, and indeed nothing greater was justifiable. Future development would give a clearer picture of the capacity of the plant which the deposit warranted.

When the reserves are fully known the risk is little different from that of more normal industrial investments, and, indeed, the interest rate required may approach the so-called safe rate. The life of the property may be precisely calculated according to the proposed annual extraction of mineral, and this will be fixed at an optimum amount according to costs. Although large tonnages mean low working costs per ton other factors must be considered. When worked out, a mine has no assets, even the plant is generally of little or no value. Where capital expenditure on plant and development is considerable, it is perhaps wise to limit production to a minimum life for the mine of 20 years, which is the period allowed for the redemption of capital expenditure for income-tax purposes.

Where the allowance for probable and possible reserves increases relatively to the positive reserves, there a higher speculative interest rate must be expected. The degree of risk to be allotted is not comparable for all types of deposits; in some cases although only a relatively small amount of positive reserves may be proved, the geologist or mining engineer may know from his experience that such a deposit is certain to persist in depth, and the risk to him

may not be as great as the proved reserves would suggest. In certain cases of a very highly speculative nature, a risk rate even higher than 30% may be advisable, but if the capital invested is to be kept conservatively within the limits warranted by the type of deposit, it should rarely be necessary to assume a rate higher than 10 to 15%.

There are, of course, instances in which little or no mineral is in sight, and money may be invested solely on the basis of favourable geological considerations. In such cases, the anticipation of profits is largely a gamble, and, when obtained, the profits may justifiably be of the order of hundreds or even thousands percent to the original investors. Cases of this nature are outside of the scope of any formula such as the Hoskold two-rate formula.

Production cost hazards

The cost of production of a mineral may be divided broadly into the following charges: development, mining, treatment, and management. These charges may be further subdivided into cost of labour, supplies, power, etc., and they will partly depend upon such factors as the form of the deposit, the volume of production, the efficiency of the method of mining and treatment adopted, and the length of time over which mining has been in progress.

It will be obvious that detailed discussion of the hazards associated with each factor involved is impossible here, and is entirely a technical matter. In a mine which has been producing for some years, the cost of production may be known with exactitude, and the future trend of costs may be judged with confidence. In the case of a new venture, estimates of costs must be based entirely on experience of adjacent similar properties, with due regard to any anticipated peculiarities of local conditions. Considerations of future costs should take into account the effects of possible improved methods of mining or treatment. As a general rule, production costs show a pronounced reduction during the life of a mine.

Transport hazards

The geographical position of a mineral deposit naturally has a direct bearing on the facility of transport and hence on the cost of marketing. In extreme instances transport costs may be so great relative to production costs that the mineral may not be profitably marketed. Given equal grades of ore and similar conditions permitting equal mining costs, a deposit of manganese ore close to the railway in Bihar, and only a short distance from the steel works at Jamshedpur, is likely to yield a greater profit than one in the Central Provinces. Iron ores in the Bailadila Range, Bastar, or in the Central Provinces, although of a high grade, cannot compete at present with ores in Bihar and adjacent Eastern States.

In the case of minerals of higher value, such as gold or mica, transport costs affect the net profit merely to the extent of the additional expense of bringing in mine supplies, other conditions being equal. But a good deposit of ruby mica in, say, Rajputana or Orissa, may not have the value of a similar deposit on the Bihar mica belt for there is a lack of skilled labour for cutting, sorting, and splitting in the former areas.

Market value trends

The market value of some minerals, such as iron ore, may vary little from year to year, whilst others may vary widely, copper, for example, ranging from £35 to £80 per ton. The prices of many minerals may be determined almost entirely by overseas markets—it is these minerals which generally vary widely in price; other minerals may have only a local demand.

Before the future average market price of a mineral can be estimated, it is necessary to trace the past variations in price. A study of the price curve will indicate the period over which the average may be taken; it will also indicate at what phase in the business cycle the industry stands at the moment (fig. 21). Commonly, if the data are considered over a sufficiently long period, the average price may show a tendency to increase or decrease and may itself be a curve.

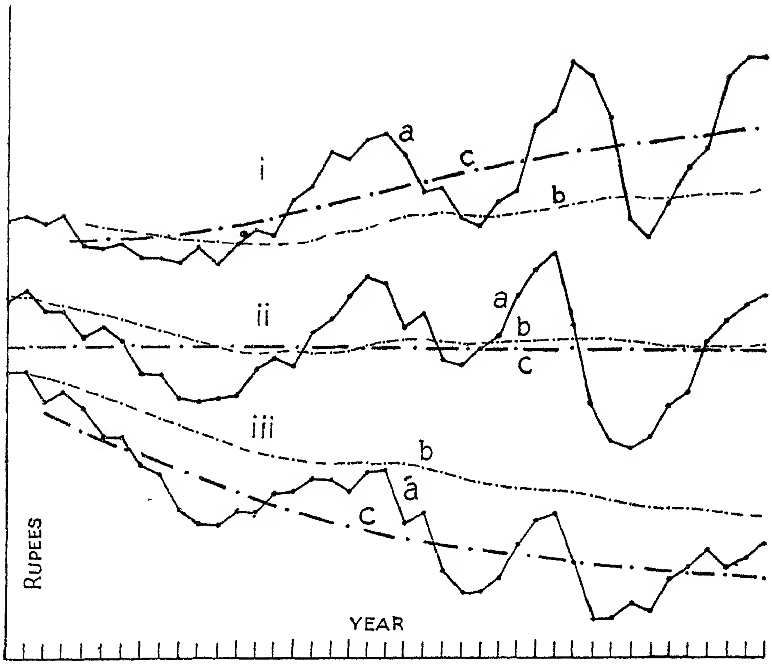

FIG. 21. Price curves showing business cycles.
(i) General increase in average price.
(ii) Fixed average price over prolonged period.
(iii) General reduction in average price.

a—price curve; *b*—average price calculated from commencement of records; *c*—apparent price trend.

It would be unwise, of course, to base estimates of future prices on the market value of the mineral at any particular moment. Still, it is remarkable how frequently the layman will judge the future of a mineral deposit by the immediate price for which the mineral is selling, whether it be during a boom period or in the trough of a depression. For a small deposit which will last only a few years it would be inadvisable to judge its value from prices extending over a long period; a close inspection of the recent price

curve with a knowledge of the accumulated stocks of the mineral and of the trend of the industry in general will provide a better appreciation of the immediate future price during the short life of the mine.

However, no study of past price tendencies will serve as a guide to the effect which such catastrophies as a world war will exert on future prices. In the case of gold, when the gold standard was abandoned the price of this metal rose spectacularly. Following the 1914–1918 war, the acute disturbance suffered by prices lasted for a few years, and after the price curves smoothed out they were further disturbed by the depression of 1931.

Profit

The estimated total profit from a mine will depend upon two sets of hazards: those related to total costs and those related to total income. The hazards, in correctly estimating total mining costs, are little different from the hazards in estimating the costs in many manufacturing concerns. The total income is dependent on the total mineral reserves and on the market prices during the life of the mine. The market prices of minerals on the whole show no greater tendency for variation than do many other raw materials or manufactured articles, but the hazard of total reserves—or life—is peculiar to mining. This hazard of the life of a mine is covered by the speculative rates of investment interest given in Table 8, taking into account some of the difficulties peculiar to mining—collapses, accidents, fire, etc. In valuation calculations, the remaining hazards are included in the individual estimates of the various items, as they would be in any other mode of business.

With a closely approximate knowledge of the costs and of the trend of sale prices, the profit to be expected from a mineral deposit may be deduced with reasonable accuracy. This estimated profit may be very accurate for the immediate future, but, with lengthening of the period over which the estimate is made, individual items may diverge from the predicted average.

It is a fallacy to assume that an increase in selling price will be reflected by a commensurate increase in profit. It is likewise inadvisable to assume that a reduction of price means an equivalent decrease in profits, or that a change in costs will be accompanied by a parallel change in profits. The difference between the price per ton and the cost per ton—'the profit spread'—is partly governed by factors which may extend far beyond the immediate industry of the particular mineral. The selling price will vary with the general purchasing power of money (that is, with the general commodity index), and with the mineral's value relative to other commodities; each item of cost will be subject to similar variations. There may be a certain amount of lag in the effect of these two variables on profits, but over a sufficiently long period their effect is complete. Increased prices are generally paralleled by increased costs of stores, new equipment, etc., and increase in wages. Also, periods of increased price generally coincide with increased business activity, and labour may not only be scarce and dearer, but also less efficient.

In mines in which the mineral requires to be concentrated there is an additional factor which tends to keep the profit spread constant. Such mines generally contain a large amount of low grade material which, under average working conditions, it would not pay to mine and treat. As soon as the profit spread tends to increase, it becomes possible to mine and treat lower grade material, thus bringing back the profit spread to the average: this results in an increased life for the mine.

It is thus apparent that the actual profit spread will not vary so widely as the sale price or the cost per ton. Hence, there is some justification for the assumption that once an estimate of the profit spread is established as reliable for the immediate future, this profit spread will be subject to such similar fluctuations as take place in other comparable industries, and that, therefore, the hazards attached to the speculation are no greater than those of other industries of the same nature. A property with 20% better prospects of success than an adjacent similar property is likely to

retain that degree of enhanced prospects throughout the vicissitudes of a business cycle.

Valuation of a working mine

The valuation of a mine which has been in operation many years is the simplest case. The total costs can be determined with fair exactitude, due allowance being made for any possible improvements in technique. Reserves may be closely estimated and some allowance made for further possible reserves. The present value may then be determined by the use of Hoskold's formula.

During the examination of the property, it may become apparent that additional development work is immediately necessary to bring the mine up to the required rate of production. At the same time new plant may also be necessary. If this additional capital expenditure is to be incurred at once, the full amount should be deducted from the present value as determined by Hoskold's formula.

Example 20.—A colliery is expected to yield an annual profit of Rs60,000 for a period of 20 years. It is apparent, however, that a sum of Rs20,000 must be spent immediately on underground development work, and urgent plant requirements will cost Rs80,000. With speculative interest rate at 7% and safe rate 4%, what price should be paid for the property?

$$C = \frac{60{,}000}{\dfrac{\cdot 04}{1\cdot 04^{20}-1}+\cdot 07}$$

$$= \text{Rs}579{,}252$$

$$\text{Cost of immediate improvements} = \quad 100{,}000$$

$$\text{Purchase price} = \text{Rs}480{,}000$$

It may not be possible to purchase the plant immediately, and, although the development work can be done at once, the old plant may suffice to carry on for the next five years. In that case, the present value of Rs80,000, the estimated cost of the plant, will be deducted, taking the interest rate at, say, 4%.

$$\text{Present value of Rs}80{,}000 = \frac{80{,}000}{1{\cdot}04^5}$$

$$= \text{Rs}65{,}754$$

$$\text{Development} = \text{Rs}20{,}000$$

$$\text{Rs}85{,}754$$

$$\text{Purchase price} = \text{Rs}579{,}252 - 85{,}754$$

$$= \text{Rs}493{,}500$$

The mine may be purchased during a period of depression when, although it may not be profitable to work the mine, plant and development costs may be cheap. It may be considered advisable to defer production for five years, and in the interval spend Rs20,000 on improvements at the beginning of each of the five years. Assume 7% still as the speculative interest rate, 4% as the safe rate, 6% allowed during the deferred period, and 4% as interest on the annual amount to be spent.

$$\text{The present value of the mine} = \frac{\dfrac{d}{\dfrac{i}{R^n-1}+i'}}{(1+i'')^m} = \frac{\dfrac{60{,}000}{\dfrac{\cdot 04}{1{\cdot}04^{20}-1}+\cdot 07}}{(1+\cdot 06)^5}$$

$$= \frac{579{,}252}{1{\cdot}3382}$$

$$= \text{Rs}433{,}000$$

Present value of annual improvement expenditure—

$$= 20{,}000 + \frac{20{,}000}{1{\cdot}04} + \frac{20{,}000}{1{\cdot}04^2} + \frac{20{,}000}{1{\cdot}04^3} + \frac{20{,}000}{1{\cdot}04^4}$$

$$= 20{,}000 + 19{,}231 + 18{,}491 + 17{,}780 + 17{,}096$$

$$\text{Purchase price} = \text{Rs}92{,}600 = \text{Rs}340{,}400$$

Valuation of an undeveloped mine

In estimating the present value of a new mine, the total reserves are determined and a commensurate amount added for probable and possible ore. The prospective annual gross receipts

may then be calculated. Next, the costs are estimated just as for a working mine, using the data which local conditions have indicated will approximately prevail. These will include amortisation of such capital charges as plant and development, interest on working capital, revenue development, actual mining costs, treatment costs, transport, administrative and other costs (taxes, insurance, commission, etc.). From the net profit thus determined, the present value may be calculated using the speculative interest rate compatible with the type of deposit.

CHAPTER XVIII

VALUATION OF MINING SHARES

The average small investor is interested more particularly in the price of the shares of any mining company, and in the return which he may expect from those shares. Not uncommonly mining shares are regarded as of a far more speculative character than are the shares of manufacturing concerns like jute, cotton, or flour mills, and accordingly mining shares are more frequently bought as a speculation and not as an investment, profit being expected rather from a rapid rise in share values than from dividends. This chapter is written not so much for the speculator in share values, whose view is naturally of short term, but for the small investor who must look to profits from his investment over a long period of years. However, even the speculator in share values, if he is wise, must consider the relation between his purchase over its prospective short period with the longer cycle of vicissitudes of his purchase, for it is only by doing so that he can form a reliable opinion as to the upward or downward trend in the price of the shares.

The small investor can normally hope to have little more than a superficial insight into the operations of the mine in which he is interested. If it is a new mine, about to be developed, he must trust the technical report incorporated in the prospectus, and the reliability of that report will vary with the technical experience and integrity of the mining engineer or geologist who made the examination of the property. It cannot be too strongly emphasised how completely the investor is dependent on this technical advice, and therefore with what care the technical adviser must be selected by an honest company promoter. It is true, of course, that honest technical advice is by no means always correct, but its errors are likely to be rare compared with the so-called advice of the layman in such matters. Yet mines have been frequently floated in India with quite considerable capital without any such basis as a technical

report. One deterrent, apparently, is the promoter's diffidence at paying the requisite fee—only too frequently advice is expected for nothing. The same promoters would have little objection to paying the high fees for legal advice, but do not appreciate that reliable mining advice is perhaps backed by even longer specialised training and experience, combined with a shrewd ability to weigh many varying factors. Like the services of a good lawyer in a legal enquiry, the services of a good technical adviser in mining may prevent the loss of very large sums of money. The layman should look upon the cost of technical advice from the point of view of what he is likely to save from it as well as what he is likely to gain. He may then, perhaps, appreciate its true value, and not complain so much at its cost when the report is unfavourable.

A well-balanced technical report in the prospectus of a new company should indicate clearly all the possibilities for and against the success of the project, and summarise the adviser's views of the prospects of the mine under the conditions which it is anticipated will rule during the life of the mine. The report should indicate clearly what return may be expected on the capital invested. The investor should be able to judge for himself whether that return is commensurate with his desired rate of interest for this type of investment and with the current safe interest rate on redemption of capital.

The small investor, interested in a working mine, must rely for his knowledge of the mine on the periodical reports issued by the company. He must accept those reports as being reliable, but no reports of this nature can give a detailed picture of the technical condition of the mine such as a layman may be expected to understand fully. However, the shareholder should be in a position to collect statistics of past dividends and of the annual changes in ore reserves and production. With a knowledge of the general trend of the selling price of the mineral, of the accumulated stocks of mineral on hand, and of business in general, he should be able to judge the likelihood of the persistence of those dividends. He may then calculate for himself the value of the shares, using the speculative interest rates given in Table 8, if he wishes, and

may compare his estimated value with the market price of the moment.

A few examples may be given.

Example 21.—An extensive iron and steel concern is paying $12\frac{1}{2}\%$ dividends. The iron ore reserves of this company are sufficient for at least 100 years' supply at the present rate of smelter production, and the company's coking coal and limestone resources have a commensurate life. Assuming the ruling rate on safe investments is 3%, what should be the market value of the shares?

With reserves sufficient for at least 100 years, the investment may be treated for all practical purposes as a perpetuity, and the investor has no need to take into account the return of his capital. It is assumed, of course, that the company has taken all the usual precautions of building up the necessary funds for depreciation of plant, etc. Hence, so far as the investor is concerned, the investment carries no more risk than many other industries of reputedly steady dividends. The industry is sound, the market demand expanding, prices and costs are subject to no more than the usual cycles of boom and depression periods, with the added risk of strikes, etc., affecting one or other side of the company's operations. As the 'safe' investment rate is 3%, this form of investment may be expected to yield $4\frac{1}{2}$-5%—assume the latter figure.

$$\text{For a perpetuity, } C = \frac{d}{i} = \frac{\cdot 125}{\cdot 05}$$
$$= 2{\cdot}5$$

Hence the shares are worth *250%* of their original value.

Example 22.—A coal mine is paying dividends at the rate of 12%. Reserves are certain to last 20 years at the present rate of working. No unusual capital expenditure is contemplated during the next 20 years, and plant depreciation for the period is covered by a reserve fund. With safe investment rate of 4%, what are the shares worth?

The risk rate on this investment may be regarded as reasonably low; coal mining is subject to fluctuations similar to other industries, but perhaps more commonly liable to strikes, strong competition, and to possible loss of reserves by fire or collapse of workings. As

a past consistent dividend payer the risk in this mine cannot be regarded pessimistically, and a rate between 5 and 6% would be reasonable—assume the latter figure.

$$C = \frac{d}{\frac{i}{I^n - 1} + i'} = \frac{12}{\frac{\cdot 04}{1\cdot 04^{20} - 1} + \cdot 06}$$

$= 1\cdot 28$, or *128%* of the original share value.

Example 23.—A colliery is paying $12\frac{1}{2}$% dividends on Rs10 shares, which are now priced at Rs12-8-0. With speculative rate for this class of share at 6%, and safe rate at 3%, what is the minimum life for the reserves which a careful investor would expect?

The rate of dividend on Rs12/8 is $\frac{10}{12/8} \times \frac{12\cdot 5}{1} = 10\%$.

The dividend overplus, $10 - 6 = 4\%$, is the amount available annually to redeem capital. It is required to find the number of years it will take for this 4% to accumulate to 100%, at 3% interest.

$$n = \frac{\log\left(\frac{i}{f} + 1\right)}{\log I} \ldots\ldots\ldots\ldots \text{(formula xxi, p. 177)}$$

$$= \frac{\log\left(\frac{\cdot 03}{\cdot 04} + 1\right)}{\log 1\cdot 03} = \frac{\log 1\cdot 75}{\log 1\cdot 03}$$

$= 19$ years.

Example 24.—A mine has reserves for 20 years. What dividend is expected, with required speculative return at 6% and current safe rate at 4%?

$$C = \frac{d}{\frac{i}{I^n - 1} + i'} \ldots\ldots\ldots\ldots \text{(Hoskold formula)}$$

$= d \times 10\cdot 6858$ (Table 17)

$$d = \frac{C}{10\cdot 6858} \qquad (C = 100\%)$$

$= 9\cdot 5\%$

Example 25.—A lead-silver-zinc mine which has paid consistent dividends of $12\frac{1}{2}\%$ is extracting ore down to 1,200 feet in depth, and has reserves blocked out sufficient for 3 years. In addition, a pilot shaft has been carried down to 2,500.feet at which depth a crosscut from the pilot shaft to the lode shows that ore of the same grade as worked at 1,200 feet is still available. During the past 12 years of its life costs have been reduced, as also has the grade of ore which can be profitably mined. It is expected that dividends will persist provided the sterling prices of lead and zinc remain above a certain figure. What are the shares worth at present?

Assume, for the moment, that only the positive reserves blocked out can be considered. The price of lead and zinc are at their peak, world stocks are small, the plant is in perfect condition, labour quiet. On these assumptions, during the 3 years it is practically a safe investment, risk rate would be 5%, rate for capital redemption 4%.

$$C = \frac{d}{\frac{i}{I^n - 1} + i'} = \frac{\cdot125}{\frac{\cdot04}{1\cdot04^3 - 1} + \cdot05}$$

Present value = 33·75% of the original share value.

However, this assumption ignores the evidence disclosed by the pilot shaft, that ore is persisting in depth. The evidence gives strong hopes that there may be reserves for a further 15 years, so that the prospective life is now 18 years, but the risk rate on such an expectation must now be taken at a much higher figure—10% would perhaps be a minimum. The price of metals is likely to vary widely during the period, and labour troubles must be expected, but quite a comfortable reserve fund has been built up which will serve to smooth out the more severe profit fluctuations.

$$C = \frac{\cdot125}{\frac{\cdot04}{1\cdot04^{18} - 1} + 10}$$

Present value = *90*% of the original share value.

Assuming the mine paid the first dividend one year after the commencement of operations, within what period will the original shareholders have had a complete return of their investment?

$$n = \frac{\log\left(\frac{i}{f}+1\right)}{\log I} = \frac{\log\left(\frac{\cdot 04}{\cdot 025}+1\right)}{\log 1\cdot 04} = \frac{\log 2\cdot 6}{\log 1\cdot 04}$$

$$= 24 \text{ years.}$$

It is apparent that the most important factor, so far as mining is concerned, is the reserves or future life of a property. So long as a definite life is assured, mining is clearly scarcely more risky than other forms of investment, indeed, the risk attached to certain forms of mining investment may be less than in certain other industries in which there is a tendency to overproduction.

This factor—life of the mine—cannot be too strongly emphasised. Every annual report of a mining company should briefly but clearly state the company's position in this respect, and give information on the positive reserves, with also any information available which would suggest a minimum future life, so that the investor can adjust his expected risk rate to the facts available. This information should not be withheld from the investor, it is his right to have it just as much as it is the directors'. It is also a right of the general public interested in such shares. A company unwilling to issue the facts has something to hide, and the investing public might do well to avoid its shares. It is true that an unscrupulous management may issue an incorrect statement of reserves, but the risk of an unscrupulous management must be accepted in any business.

The above observations apply, obviously, to a mining company floated to work a particular mineral deposit, and which, once that mineral deposit is depleted, will go out of business. There are, of course, certain mining companies which accumulate a considerable capital redemption fund during the life of the mine, with the intention of investing this in another property on the conclusion of their present operations. To such a company's dividends the Hoskold formula does not apply, and the investment may be

considered more or less as a perpetuity with only the risk rate to be taken into account. Similarly, some companies spread their operations over several deposits, bringing new properties into development as old ones are worked out, and sustaining a reserve fund always well able to cope with new capital requirements as they arise. In this case also, the investor need consider only the risk rate for his investment and may ignore the redemption of his share capital.

CHAPTER XIX

MINING CONCESSION TERMS IN INDIA

PROCEDURE

Except in the permanently settled areas of British India, the mineral rights are vested in the provincial Governments, or, in the Chief Commissioner provinces, in the Central Government. In permanently settled areas, the zamindars claim the mineral rights, and this has been accepted as a matter of administrative practice although the point has not, perhaps, been indubitably established in law. In the Indian States, the mineral rights are vested in the States.

Those interested in the mineral industry of a particular province are well advised to obtain a copy of the local mining concession rules, and to familiarise themselves with the conditions under which mining concessions are granted.

Before a prospecting license or a mining lease is granted to any person in British India he must obtain a certificate of approval from the particular Government, for which a fee of Rs50 is generally payable. Certificates of approval can be renewed year by year on payment of Rs10.

A prospecting license, granted by the provincial Government, permits the licensee the sole right to prospect for minerals over a specified area of land for a term of up to two years, but which may be renewed at the discretion of the local revenue officer. The fee payable is generally up to one rupee per acre per year, and, in addition, royalty may be charged on the mineral removed.

A mining lease is granted by the Government concerned through the local revenue officer. A prospecting license need not necessarily have been held prior to application for a mining lease of any specified area. The advantage of a prospecting license is that the licensee is able to prospect the area thoroughly before applying for a mining

lease, thus enabling him to reduce the area covered by the mining lease to the minimum necessary for the efficient working of the deposits he has found.

The terms upon which mineral leases are granted vary widely in different parts of India. Throughout British India, up to 1936, the terms were consistent for the various minerals, but since that year, when full control of the mineral rights was taken over by the provincial Governments, there has been a strong tendency for each province to introduce individual terms. In the States and zamindaris, each new mineral lease is treated as a separate proposition and liable to such rates as may be decided at the time of application, but many States follow the standard forms of British India leases.

The terms under which certain minerals, known as 'minor minerals', are leased are not determined by the same rules as are applied to minerals in general. Each province has its own definition of what is a minor mineral, but it generally comprises such materials as slate, building stone, limestone, and clay. The significance or logic of this differentiation is entirely incomprehensible to the author, and has not infrequently given rise to unnecessary discussion. The distinction of this group of 'minor minerals' should be abandoned, and all minerals without exception brought under the same rules.

It is possible to discuss only in a general manner, here, the terms under which mining leases are granted. The settlement of the terms which may be wisely imposed should be founded on a knowledge of the various factors which may affect the particular industry. In principle, the object should be for the lessor (whether this be Government, State or zamindar) to obtain the maximum revenue from the lessee without, however, so restricting the latter's enterprise as to prevent the efficient working of the deposit.

The principal items in any mineral lease issued by Government are: area, period of the lease, surface rent, minimum royalty or dead rent, and royalty. Zamindars, and in some cases the Indian States, not uncommonly merge the three revenue items—surface rent, dead rent, and royalty—into a fixed annual rental. The

Bihar Government has merged rent and royalty into a fixed annual rental only in the case of the 40-acre mica mining leases within the Kodarma Reserved Forest, where the annual rental is Rs12 per acre.

An additional payment, known as *salami*, is commonly required by the States and zamindars when the lease is first signed, but is not required under leases issued by provincial Governments. Salami may be regarded as the present value of part of the royalty, provided that it is credited to the State and not to the Ruling Chief's private income.

Area of lease

When Government is the lessor, the aggregate area of mining leases held by a single lessee in any one province may not exceed 10 square miles, except in the case of petroleum and natural gas for which the limit is 150 square miles.

The actual area covered by a mining lease will, of course, vary with the particular type of mineral deposit. In general, such deposits as coal, iron ore, limestone, and copper, require a considerably larger lease area than, say, china clay and ochres. In Bihar, the areas of iron ore leases granted to the larger companies have been based on 100 years' reserves of ore, according to the estimated annual requirements of each company. Where several deposits of a mineral are scattered over a fairly limited area, the lessee should not be permitted to take up a number of separated leases leaving small unleased areas between, but should be compelled to take the whole within reasonable limits.

In that part of the Bihar mica belt covered by the Kodarma Reserved Forest a method of lease allotment has been adopted which is peculiarly suitable only to this area. A great number of mica deposits are scattered over a large part of the Reserved Forest, which has been divided into 900 squares of 40 acres each, and these are leased at a fixed rent for each square (now Rs12 per acre), no separate royalty being charged on the mica produced. This method of lease allotment is applicable in the Kodarma Reserved Forest only because the deposits are numerous and closely spaced; it is not

necessarily suitable to other types of deposits, and should not normally be applied elsewhere.

In zamindari land a mining lease not uncommonly covers the whole area of small zamindaris. The boundaries of a coal mining lease may be determined by the zamindari boundaries, and the latter may not always be the best limits for the efficient working of the coal seams in a particular colliery.

Period of lease

The maximum period for which a mining lease is granted by Government is 30 years, but a lease may contain a clause permitting renewal for a further period of up to 30 years and, in the case of iron ore, a second renewal of 30 years.

The actual period of many leases is generally rather less than the 30-year maximum. Some deposits are small, and a long lease is unnecessary; others, such as iron ore, are large and take an extended period to deplete. Most deposits require machinery to work them, and the period of depreciation on such capital expenditure permitted for income-tax purposes is 20 years. Hence, a minimum of 20 years is generally advisable for mining leases, although in some cases 30 years may be preferable. Where there is likely to be a considerable change in the development and prospects of the particular industry in the future, the shorter period permits an earlier adjustment in the royalty and other terms to suit changing conditions.

Surface rents

Surface rent is payable on that portion of land, within a lease, which is occupied by the superficial part of the mine and by works, offices and quarters. It is generally a fixed amount dependent on the actual local value of the land occupied and, in the past, has been assessable under the revenue and rent law. In the Commissioner provinces, where the mining concession rules are under the Central Government, in those cases which are not assessable under the revenue and rent law the surface rent is fixed

between the limits of 4 annas and one rupee per acre. Recently, in Bihar, there has been a tendency to charge a consistent surface rental of Rs10 per acre.

Many zamindars do not charge surface rent, but include all charges within the general annual rent for a mineral lease.

Dead rent, or minimum royalty

Dead rent is a fixed charge for the whole area of a mining lease, generally calculated at a certain rate per acre. Dead rent and royalty are not both payable for the same period, but only that which may be the greater in any year. Dead rent is, therefore, a minimum royalty; it is not payable for the first year of an original mining lease.

As a general rule, it may be said that in the early years of opening up a deposit the dead rent will be paid, whereas later, when the deposit is worked more vigorously, royalty will provide the main source of revenue to Government for the deposit. Hence, the amount of dead rent should not be so excessive as to be a heavy burden on the mine just at that time when its expenses are the greatest and its revenue a minimum. It should vary in amount according to the type and size of individual deposits. Some minerals may have a low market value and may be in small pockets scattered over a wide area—obviously, in such a case, the dead rent should be very low. In another case deposits of a more valuable mineral may be scattered over an equally wide area, and here a somewhat higher dead rent is advisable. Yet again, a mineral of low value may be concentrated within a small area, so that a dead rent higher than in the first case is permissible, whilst if large reserves of a mineral of high value are concentrated in a small area a commensurately high dead rent is legitimate.

Although it is advisable to keep dead rents at rates which will not hinder development of the mines, there may be the danger, if the rates are very low, that the deposits may be taken on lease by inefficient concerns which have not the requisite capital to work the minerals vigorously. Inefficient and under-capitalised concerns may result in Government or other lessors (State, zamindars)

losing revenue on royalties which more efficient companies would have paid, and ultimately large assets may be lost to the lessors because of wasteful working. Also, if the dead rent is too low, the tendency will be for the lessee to obtain a larger area than is really necessary.

In the past the following minimum dead rents have been charged under Schedule III of the Mining Concession (Central) Rules. These minima were generally largely exceeded according to circumstances, and in recent years there has been a tendency to increase the amounts. In Bihar, for example, the minimum dead rent for iron ore is now generally Re1 per acre and rates up to Rs2 have been charged recently.

(1) Coal, lignite, minerals used in agriculture and chemical manufactures, such as bauxite, gypsum, iron pyrites and pyritous shales.	4 annas per acre.
(2) Gold and silver, precious stones, minerals (not included in (1) above, except iron ore and natural petroleum (including natural gas)).	Re1 per acre.
(3) Iron ore	1 anna per acre.
(4) Natural petroleum (including gas).—For areas held under leases within the territories administered by any one Chief Commissioner—	
For leases of areas not exceeding a total of 10 square miles.	Re1 per acre.
For leases of areas exceeding 10 square miles but not exceeding 50 square miles.	Re1 per acre for the first 10 square miles; Rs2 per acre for the excess over 10 square miles.
For leases of areas above 50 square miles but not exceeding 100 square miles.	Re1 per acre for the first 10 square miles; Rs2 per acre for the next 40 square miles; Rs5 per acre for the excess over 50 square miles.
For leases of areas exceeding 100 square miles.	Re1 per acre for the first 10 square miles; Rs2 per acre for the next 40 square miles; Rs5 per acre for the next 50 square miles; and Rs10 per acre for the excess over 100 square miles.

NOTE.—These minima are purposely fixed low, but they are liable to be largely exceeded, according to the value of the deposit and degree of development of the country.

Royalties

Royalty is the amount charged by the lessor on the mineral removed, and may be regarded as the lessor's sale price for the mineral. Just as a shopkeeper has his stock for sale, so a mineral lessor has the mineral in the ground for sale for mining, treatment, and marketing, but with this difference: whereas a shopkeeper can obtain fresh stock, the mineral lessor cannot renew the mineral sold. Thus, a mineral lessor is left without his material asset on exhaustion of the deposit. If, therefore, he desires to leave his estate in at least as good a financial position at the end of the deposit's life as at the beginning he will not spend the full revenue from the mineral royalties, but will set aside a certain proportion in safe investments so that, on expiry of the deposit, the total accumulated amount invested will at least equal the total value of the original deposit. The royalty should, then, be at such a rate that the lessor is given a fair return for his capital (as represented by his mineral asset) plus an amount sufficient to redeem the value of that asset. So far as Government is concerned, when a mineral deposit is depleted Government should have derived from the royalties not only a revenue during the life of the mine, but also assets in the form of State permanent improvements to the value of the original mineral deposit. Reference will be made to this aspect of the subject later.

The value of a mineral varies at different stages of its production: it has one value to the miner as it lies in the ground, another value on being brought to the surface (known as the 'pit's mouth value'), and other values as it reaches various points of transport and, ultimately, the place of manufacture where it is to be converted into finished articles. The increase in value depends on labour costs, transport charges, etc., through the various stages. Theoretically, the value of the mineral *at the moment it is to be removed from the ground*, is the difference between the sale price of the raw material and all labour and other charges from the moment of commencement of mining it. This value may be regarded as

divisible into two parts: the lessor's selling price, or royalty, and the additional value to the miner, or the latter's profit.

Attention is drawn to the difference between the value of a mineral *at the moment it is to be removed from the ground*, and the value *in the ground*. A mineral at the moment it is to be removed from the deposit has an *immediate* market value. A mineral in the ground, awaiting to be removed some time in the future, has a present value less than the value of mineral in process of removal, the difference being dependent on current interest rates. For example, a mineral deposit may have 10 years' reserves at a certain rate of working. Each year, in the future, one-tenth part will be removed and sold, but the present value of each of the ten parts will be less the longer the interval between the present and date of removal. The sum of these present values will be less than if the whole deposit were to be removed in the first year. Obviously, then, rates of royalty are correctly based on the prospective immediate market value of minerals (their value at the moment of removal) and not on their present value (or value in the ground).

The methods to be adopted in charging royalties, and the rates, give rise to difficult problems, for a uniform basis of determination has not been regarded as equitable for all deposits. Under Schedule I of the Mining Concessions (Central) Rules, the following rates have been charged in the past:—

Coal, exclusive of dust and coal used on the works.	5% on the sale value at the pit's mouth, with a minimum of 2 annas per ton.
Coal dust	Half the rates fixed for coal.
Mica	5% on the sale value at the pit's mouth.
Natural petroleum ..	5% on the well-head value (convertible at the option of the Chief Commissioner to an equivalent charge per 40 gallons to be fixed annually) subject to a minimum of 8 annas per 40 gallons.
Natural gas	If sold by the licensee or lessee or if utilised by him for any other purpose than the production of natural petroleum or natural gas—5% on the well-head value. On gas converted into gasoline the well-head value shall be calculated on the volume of gasoline manufactured: it shall be deemed to be equivalent to the selling value of the gasoline less the

	cost of manufacture and the royalty shall be subject to a minimum of 8 annas per 40 gallons of gasoline manufactured: Provided that the 5% royalty rate shall be convertible at the option of the Chief Commissioner to an equivalent charge per 40 gallons of gasoline (not being less than eight annas) or per 1,000 cubic feet of gas, as the case may be, to be fixed annually.
Oil shale—	
(*a*) When the oil is extracted by the licensee or lessee within the territories administered by the Chief Commissioner granting the concession.	8 annas per 40 gallons of crude oil obtained therefrom.
(*b*) In other cases ..	Re1 per ton of shale mined.
Gold and silver	7½% on the profits [1] of each year taken separately or 2½% on the gross value, at the option of the Chief Commissioner.
Iron ore	One anna per ton of iron ore during the year [2] for which the tariff valuation of imported pig iron has been fixed at Rs65 per ton or less. When the tariff valuation exceeds Rs65 one anna will be added to the royalty rate for every increase of Rs15 or part thereof in the tariff valuation. Should the tariff valuation of pig iron become fictitious owing to the cessation of imports or to any other cause, a point on which the decision of the Central Government shall be final, the market value of pig iron for the purpose of the assessment of royalty

[1] Profits shall be taken to mean the excess of the revenue which is wholly derived from the sale of the mineral or minerals specified over expenditure, after all the costs and expenses chargeable to the actual working and management of the mine shall have been included. But neither depreciation nor amortisation nor Directors' fees, nor any revenue or expenditure obtained or incurred on account of share or capital transactions, or by trading, shall be brought into the account, provided that the fees of such Director or Directors as may actually direct technical operations and are specifically denoted as Managing Director or Managing Directors may be included in expenditure.

[2] Tariff valuation is fixed in December for the following calendar year, but the Chief Commissioner may, at his discretion, assess the royalty for the financial year beginning on the 1st April on the basis of the tariff valuation fixed in the preceding December.

	shall be determined by the Central Government.
Precious stones	30% on the net profits [1] of each year taken separately (for mining leases only).
All other minerals not specified above.	$2\frac{1}{2}$% on the sale value at the pit's mouth, or on the surface, of the dressed ore or metal, convertible at the option of the Chief Commissioner to an equivalent charge per ton to be fixed annually or for a term.

[1] Profits shall be taken to mean the excess of the revenue which is wholly derived from the sale of the mineral or minerals specified over expenditure, after all the costs and expenses chargeable to the actual working and management of the mine shall have been included. But neither depreciation nor amortisation nor Directors' fees, nor any revenue or expenditure obtained or incurred on account of share or capital transactions, or by trading, shall be brought into the account, provided that the fees of such Director or Directors as may actually direct technical operations and are specifically denoted as Managing Director or Managing Directors may be included in expenditure.

It will be observed that the general basis of assessment of royalty for most minerals has been $2\frac{1}{2}$% of the 'pit's mouth' value of the mineral, but a flat rate has been commonly substituted for some minerals. It is obvious that $2\frac{1}{2}$% is an arbitrary estimate of the amount which industry can afford to pay compatible with Government's revenue requirements; this rate was fixed during the early days of mining development in India, and cannot be accepted as a permanent basis of assessment of royalty.

By 'pit's mouth' value is meant the sale price of the mineral, less transport and other charges incurred between the mine and place of sale.

It will be apparent that, in the case of certain minerals, some of the material mined is not sufficiently high grade to be marketable, and is accordingly dumped at the mine. Hence royalty should be charged only on the product which is actually despatched from the mine for marketing. Material in dumps which may later be found to be marketable will be subject to royalty when actually despatched.

Iron ore may be taken as an illustration of some of the factors which must be considered in determining royalty:

In the early days of iron mining in Bihar a low rate of royalty, one anna per ton, was fixed in order to encourage the industry. Now that iron and steel smelting is well established a higher rate of royalty is justifiable. However, in view of the fact that equally high grade ore is available in the adjacent Orissa States, some of which may be better suited to certain purposes, an excessive raising of the royalty might lead to an extensive transference of mining from Bihar to the States. This, of course, is an obvious argument for a common scale of royalty charges throughout India.

Although the more equitable basis of levying royalty would be on the average iron content of the tonnage despatched for treatment the grade of iron ore despatched to the smelters varies so little that the simplest method is to levy at so much per ton of ore.

In Bihar and Eastern States, the economic percentage limit for iron ore despatched to the smelters is about 60% iron. Included within the ore deposits there are large amounts of loose fine material which cannot as yet be economically treated in this country although it would be used in other countries. Such fines are piled at the mines for use in the future and are not, therefore, wasted. Although these fines must be mined along with the solid ore, they are not despatched from the mines and are, correctly, not subject to royalty.

Certain forms of soft or powdered iron ore may be used for other purposes, such as for de-sulphurising coke-oven gases, or for the manufacture of special paints. Such materials should not be assessed on the same basis as iron ore smelted for iron; they may be sold for a higher price and should, therefore, be subject to a higher royalty.

In Bihar, there are two types of iron ore deposits: (*a*) deposits of 'solid' or bedded iron ore, and (*b*) surface debris, called 'float' ore or 'cemented float'. The former deposits contain the vast reserves and they will be the sites of iron ore mines probably for centuries to come. The float deposits generally consist of surface debris scattered over a wide area of country; they are of only temporary significance but, where the soil has to be turned over within a wide area to extract the ore, a considerable amount of damage may be done to the surface and forest. Such damage

may be compensated either by an increased royalty or surface rent, or by actual assessment of the damage. However, as there is plenty of 'solid' ore available in this region, there seems no sound reason why tracts of country should be permanently damaged merely to obtain cheaply mined float ore, and it might be preferable to refuse leases for such ore.

In the case of other ores, such as manganese, chromite and copper, there may be a wide variation in the grade or composition of the ores mined, and it would not be equitable to charge a flat rate of royalty for all grades of each mineral. The alternative then is either to charge a separate rate of royalty for each grade of ore, first, second, and third grade as the case may be, or to charge royalty at so much per unit of metal content. The latter is certainly the more equitable basis of calculating royalty, but it occasions a considerable amount of trouble in checking mining returns and analyses.

The market price of minerals varies from time to time. If the royalty is charged at a flat rate Government is not receiving an equitable return when the price is high, and the miner may be subjected to a heavy burden when the market price is low. In the case of minerals in which the royalty is 5% of the pit's mouth value, the royalty will vary according to the market price, but on account of the inconvenience and labour involved in assessing these rates of royalty, a sliding scale is often adopted in which the royalty varies periodically with the market price.

It will be seen, therefore, that the method by which royalty is to be charged should be considered separately for each type of deposit. Certain minerals such as iron ore do not vary widely in value and for them a flat rate is a simple and reasonably equitable method of assessment. For those in which the valuable constituent is subject to wide fluctuation in price some form of sliding scale is equitable.

Some provision should be made in the terms of each lease for a revision of the royalty rate periodically, as the status of an industry may alter. When an industry is in its infancy low royalties form a desirable encouragement but, once the industry is well established

and as its ramifications extend, Government is entitled to an increased share in that industry's prosperity. Or, again, a local mining industry may suffer adverse changes in consequence of competition by overseas mines. At the same time, the basis of royalty charges should be as uniform as possible throughout India, otherwise an undesirable competition between provinces may result.

Some actual royalty rates may be quoted in order to illustrate how these vary from place to place:

Iron ore.—Bihar (up to 1938), one anna per ton if the tariff value of imported pig iron is not greater than Rs65 per ton, and one anna per ton more for every Rs15 or part thereof by which the tariff value of the iron exceeds Rs65 per ton. Since 1938, 4 annas per ton is being charged pending final decision of Government.

Coal.—Bihar, 5% on the sale-value at the pit's mouth with a minimum of 2 annas per ton. For coal dust, half the rate fixed for coal. Higher rates have been the rule in zamindars' estates.

Manganese.—Bihar, 12 annas per ton for high-grade ore (47% Mn and over) or 10% of pit's mouth value when the price is Rs10 or under, subject to a minimum of 9 annas, *plus* an additional royalty of 20% of the sum by which the pit's mouth price exceeds Rs10 per ton and an additional royalty of 10% of the amount by which the pit's mouth value exceeds Rs20; 6 annas per ton for low-grade ore. Keonjhar, 6 annas per ton for manganese ore and 4 annas per ton for manganiferous iron ore. Central Provinces, 5%. Mysore, 10 annas per ton.

Chromite.—Bihar, Rs1-8-0 per ton for concentrates when the pit's mouth value is Rs10; Re1 or less per ton for lump ore *plus* an additional royalty of 20% of the amount by which the pit's mouth value exceeds Rs10, *plus* an additional royalty of 10% of the amount by which the pit's mouth value exceeds Rs20; 7 annas per ton for low-grade ores (usually less than 47% Mn). Baluchistan, 12 annas per ton. Mysore, Rs1-8-0 per ton. Bombay, 6 annas per ton. Southern Rhodesia, 6 pence per ton. Sierra Leonne, 1*s* 3*d* per ton. Cyprus, 1*s* 6*d* per ton.

Barites.—Madras, 5 annas per ton.

Kyanite.—Bihar, Rs1-8-0 per ton.

Limestone.—Bihar, $9\frac{3}{4}$ annas per ton for a quarry within 5 miles of a public railway station, 6 annas per ton if within 5 to 15 miles of a railway station, 4 annas 10 pies if more than 15 miles from a public railway station. Central Provinces, 4-5 annas per 100 maunds according to locality. Gangpur, 6 annas per 100 cu. ft.

White clay.—Bihar, Re1 per ton of refined clay when the pit's mouth price is Rs20 or under, *plus* an additional royalty of 20% of the amount by which the pit's mouth value exceeds Rs20 per ton; 12 annas per ton for crude clay.

Gold and silver.—Bihar, $7\frac{1}{2}$% on the profits of each year taken separately, or $2\frac{1}{2}$% of the gross value, at the option of the Local Government.

Precious stones.—Bihar, 30% of the net profits of each year taken separately.

Minerals for which no special rates have been provided: Bihar, 5% on the sale-value at the pit's mouth.

The above points have been considered in very general terms, as the object has been not to lay down rules but merely to outline the factors to be considered in determining rents and royalties. Every mineral deposit deserves separate technical consideration to obtain as balanced an assessment as possible both on behalf of Government's revenues and for the benefit of the industry's development.

A revised basis of royalty assessment

Any impartial survey of past Government royalty charges in India leads to the conviction that the scale adopted has been extremely modest; industry can have no justifiable cause for complaint on this score. There are cases in which the royalties were fixed at figures which were far too low at the beginning of the industry, and there are other cases in which the industry, now firmly established, could well afford to pay more for its ore to the rightful owners (the lessors) in the form of royalties. There are other cases in which the royalties, assessed on a percentage basis, have been

low because overproduction has kept down the market price to a relatively uneconomic figure.

Large deposits of a certain mineral were found in India some years ago. An overseas market for this mineral was assured, small at first but with every certainty of growing. Capital requirements for mining were a minimum, the mineral had merely to be lifted from the surface and carted away. The mineral was exported from India and sold in Europe. The Indian price was between Rs25 and Rs40 per ton, which local manufacturers could not afford to pay, so that the mineral could not be treated locally. Mining costs, if the mineral were efficiently worked, plus transport costs to the station, should not have been more than Rs5 per ton (even this is an overestimate). The lowest profits were Rs15 to Rs20 per ton, but the royalty was only Re1 to Rs1-8-0 per ton. This is little better than giving the mineral to the lessee: either the selling price in India should have been drastically lowered to permit its treatment within the country and a high export tariff placed on the mineral, or the royalty should have been at least Rs5 to Rs6.

The iron and steel trade has been well favoured in the past, not only by an inordinately low royalty (1 anna per ton of ore, in Bihar) but also by tariff assistance. The industry is now thoroughly well established in India, and the prices of its products are lower than those of any other country except perhaps Australia. The province of Bihar, which in the past practically gave its ore away for a royalty of one anna per ton when the price of pig iron was Rs65, should expect a higher price for its assets when great profits are being made, even though pig iron could probably be profitably sold at much less than Rs65; it might be fairly claimed, indeed, that the province should not be the loser merely to permit India to purchase its iron and steel at perhaps the cheapest price in the world. It is true that the iron and steel companies had to take the initial risk, but they have been treated with all magnanimity and have had a long period at low royalties. For comparison, iron ore royalties in other countries may be quoted. Between the years 1929 and 1935, the average royalty per ton of iron ore in Michigan, where the ore is similar to that in India but of slightly lower grade, was

28·59 cents, *i.e.*, about 12 annas at the normal rate of exchange, and was equivalent to about 33% of the gross *ore profit* (exclusive of royalty and interest on borrowed money). Royalties greater than 1*s* 6*d* per ton are paid in Great Britain on ore of lower grade than that in India. With the raising of royalty on iron ore in India to 4 annas, this adds 5-5½ annas per ton to the cost of pig iron, and it would obviously be absurd to insist that a heavy burden is imposed on the industry. Future royalties of Re1 per ton are by no means improbable, nor would they be a severe burden on the industry or the consumers.

There have been instances in India in which the productive capacities of mines have been well beyond the local or overseas market requirements for the particular mineral. The result has been intense local competition, which reduced the market price to a fictitious or uneconomic value, leading at the same time to such reduction of costs that the future efficiency of the mines has been jeopardised. A restriction on the number of leases granted for the working of such a mineral would have meant that the working mines obtained a price for their product more in keeping with its true value or worth to industry. Royalty charges could, at the same time, have been raised to a figure more compatible with the real worth of the mineral.

If the royalty rate were raised on certain minerals, the market prices of which were absurdly low because of severe competition amongst producers, there would be an immediate chorus of dissension on the grounds that the industry was being severely handicapped. On the contrary, however, the country is losing considerable revenue in such cases, merely to permit unnecessary competition amongst a surfeit of producers. Far more will be gained by a wiser spreading of the country's production from its depleting assets over a long period of years than over a short period if, by so doing, the maximum value in marketing, the maximum efficiency of working, and the maximum amount of mineral production results. A considerable increase of the royalty would, in some cases, lead to a much-needed reduction of competition, and the market could still afford to pay the increased prices which would result.

An example of the above features is perhaps provided by the coal industry, in which there has been intensive competition consequent upon excessive capacity for production. Prices as low as Rs2-8-0 per ton have been paid for coal, and the minimum royalty of 2 annas per ton, in lieu of the 5% of the pit's mouth value, has not been unknown. This may be compared with coal royalties in Great Britain which have ranged up to 7*d* per ton. However, in eastern India there is the difficulty of competition between the various fields consequent upon their different distances from the main market, Calcutta, with varied transport costs. It might be possible to adjust this difference by a scale of royalties graded according to transport charges to Calcutta.

It is obvious that the settlement of royalty rates has been empirical. The lessor (provincial Government, State, zamindar) must recognise that a low rate of royalty is often advisable in order to establish an industry firmly; the lessee must recognise that the lessor is entitled to an increased return for his depleting asset when the industry is established. By the establishment of an industry is meant the stable existence in the country of that industry and not merely the ability of an *individual* firm to make profits. Some firms may not make profits either because they are inefficiently managed or because of other reasons independent of the trade as a whole; these reasons provide no argument that such firms should pay lower royalties than others. Although rates of 2½–5% of the pit's mouth value may be advisable when an industry is first established, for most minerals such low rates do not give the lessor (*i.e.*, ultimately the community in general in the case of provincial Governments) a fair return for the asset he is selling.

The question may be asked: Is there any formula whereby an equitable rate of royalty may be determined?

In a manufacturing business the costs may be regarded as consisting of two parts: (*a*) the cost of raw materials, R, and (*b*) the cost of working and management, C, in which will be included all capital depreciation and similar charges. Let X be the percentage of the total cost required as gross profit, and V the market price of the manufactured article, then

$$R+C+X(R+C) = V$$

$$R = \frac{V}{1+X} - C \qquad \ldots \qquad \ldots \qquad \text{(xxv)}$$

$$\begin{aligned} \text{If } X &= 10\%,\ R = \cdot 9V - C \\ X &= 20\%,\ R = \cdot 83V - C \\ X &= 50\%,\ R = \cdot 67V - C \\ X &= 100\%,\ R = \cdot 5V - C \end{aligned}$$

In using such a formula as this in mining the rate of gross profit required for the particular mineral and mine may be decided at the time a mining lease is granted, and should remain fixed for the first five years; in this formula as applied to mining, R = royalty, C = cost per ton, V = market price or pit's mouth value per ton. Should the royalty as calculated be less than the dead rent, then only the latter would be charged. After the first five years a profit percentage representative of the industry in general would be substituted, whilst for V and C the average market value and costs for the industry as a whole would be taken. In order that the mine may know its royalty position at the beginning of any one year, the average V and C for the previous five years may be used in the formula. The profit percentage used in the above formula, and based on total cost, is, of course, different from the speculative interest rate, based on capital, quoted in Table 8 for use with the Hoskold formula.

Such a formula gives to the owner or lessor of the mineral the true sale price of the mineral at the moment it is to be removed from the ground, and permits the lessee a full profit according to the rate for the particular mineral. The formula also permits Government, by its determination of the profit rate in any particular instance, to vary the royalty according to circumstances. For example, a mineral from a certain province may be mined either for manufacture in the country or for export. Obviously a company which treats its ore locally should have favoured consideration over one which merely exports, as the country benefits in many ways from treatment of the ore—a high royalty is indicated for the exporting company. Assuming that the pit's mouth value of the ore

is Rs3, and total mining costs are Rs2-4-0, for export ore a profit rate of 10% would give a royalty of 7 annas, whilst a profit rate of 15% on ore to be treated locally would provide a royalty of $5\frac{1}{2}$ annas.

For zamindars who prefer to obtain a fixed income as royalty for their minerals, this formula can be used by anticipating average figures for V and C, and applying a profit percentage acceptable for the property. This calculated annual income, or royalty, can be converted into a present value by the use of the Hoskold formula, and the mining rights either sold outright for that figure, or a salami charged and the remainder recalculated to give a definite income during the life of the mine.

When the total capital requirements are fully known, the Hoskold formula offers an alternative method of calculating royalty. The annual profit demanded by the speculative interest rate for the mineral, quoted in Table 8, may be calculated by the Hoskold formula. The actual probable profits may be estimated from the known average market price and costs. The difference between the estimated actual profit and the required speculative return per ton is the amount which the mining company should be able to afford for its ore in the ground, *i.e.*, the royalty.

Example 26.—A mineral deposit is estimated to make a profit of Rs50,000 annually (exclusive of royalty) over a period of 20 years, producing 50,000 tons per annum. Capital required is Rs2 lakhs. Speculative interest rate, 15%, safe rate, 4%.

$$\text{Profit demanded from capital} = \frac{200{,}000}{5{\cdot}4472} \quad \text{(Table 17.)}$$

$$= \text{Rs}36{,}700$$

$$= \text{Rs}0{\cdot}734 \text{ per ton.}$$

$$\text{Estimated profit} = \frac{50{,}000}{50{,}000} \quad = \text{Re}1{\cdot}0 \text{ per ton.}$$

Fair price for mineral as removed from the ground

$$= \text{Rs}0{\cdot}266 \text{ per ton}$$

$$= \textit{4 annas royalty.}$$

The mineral rights might be sold outright, in which case the present value of the annual royalty would be—

$$C = \cdot 266 \times 50{,}000 \times 5{\cdot}4472 \quad \text{(Table 17.)}$$
$$= \text{Rs}72{,}400$$

and the total capital required would be Rs272,400, which, at the interest rates quoted, would yield an annual dividend of Rs50,000.

It may be of interest to determine the value of a mining property to Government. To Government, the value of a property on which it has given a mining lease is dependent on the royalties; the value may be calculated either as a present value, or as an ultimate value to which the royalties plus interest will accrue on exhaustion of the deposit. In determining the present value to Government, the Hoskold two-rate formula does not apply as Government cannot expect a risk rate for its assets, and the interest rate for fund accumulations should be based on the average Government loan rate.

Example 27.—Government is obtaining a royalty of Rs10,000 per annum for a certain mineral property, for which a life of 25 years is expected. The Government loan rate is 3%. What is (*a*) the present value of the property to Government, (*b*) the total amount which will accrue to Government for the deposit, (*c*) the annual sinking fund which Government should regard as replacing the deposit, and (*d*) the true income which Government is obtaining from the property?

$$(a)\quad C = \frac{a(I^n - 1)}{iI^n} = \text{Rs}175{,}000 \qquad \text{(Table 16.)}$$

$$(b)\quad S = \frac{a(I^n - 1)}{i} = \text{Rs}365{,}000 \qquad \text{(Table 15.)}$$

$$(c)\quad f = \frac{Ci}{I^n - 1} = \frac{175{,}000}{36{\cdot}4593} = \text{Rs}4{,}800 \qquad \text{(Table 15.)}$$

(*d*) True income $= \text{Rs}10{,}000 - 4{,}800 = \text{Rs}5{,}200$.

Hence, Government commences with an asset valued at Rs175,000; at the end of 25 years the asset is worth *nil*, but its place has been taken by public works valued at Rs175,000. During the period, Government has drawn an income of Rs5,200 per year on capital valued at Rs175,000 initially, and at *nil* in 25 years.

CHAPTER XX

THE MINES ACT

Anyone directly concerned with the working of a mine, however small, should secure a copy of the Indian Mines Act, 1923, with all subsequent amendments. Under this Act, regulations have been enforced for the working of mines in India: the Indian Metalliferous Mines Regulations, 1926, the Indian Coal Mines Regulations, 1926, and Regulations for Oil Mines. The first mentioned is misnamed as it applies to all mines other than coal or oil mines, whether metalliferous or not.

The Mines Act and Regulations are extended to the whole of British India; mines within the Indian States do not come within the scope of the Act, and their working is governed by local regulations. As the Indian Mines Act is concerned mainly with provisions for health and safety in mine working, and is designed for this purpose on the basis of prolonged experience, all Indian States would be well advised to follow the terms of the Indian Mines Act, some already do so.

Managers of coal mines must possess certificates of competency issued under the Mines Act, but such qualifications are not demanded for the management of other mines. It cannot be too strongly emphasised, however, that mine owners should, in their own interests, employ competent technical management.

In accordance with Section 3(*f*) of the Indian Mines Act ' "mine" means any excavation where any operation for the purpose of searching for or obtaining minerals has been or is being carried on, and includes all works, machinery, tramways and sidings, whether above or below ground, in or adjacent to or belonging to a mine: provided that it shall not include any part of such premises on which a manufacturing process is being carried on unless such process is a process for coke making or the dressing of minerals'. The Governor General in Council has the power to exempt certain

areas, groups and classes of mines or parts of a mine from the provisions of the Act. Such exemption has been granted to the following classes of mines:—

1. Mines of kankar, murrum, laterite, gravel, sand, clay (not including kaolin, china clay or white clay), fireclay, ochre, stone, earth, fullers earth, barite, bauxite, slate, and limestone.

   Certain specified mines have not been granted this exemption. Also, it does not apply to soapstone or steatite mines. Once the depth of an exempted mine reaches 20 feet, or the daily number of persons employed in the mine is more than 50, particulars must be forwarded to the Chief Inspector of Mines and the District Magistrate, and the mine is liable to come under the Mines Act.
2. Borings and oil wells.
3. Mines or parts of mines in which excavation is being carried out for prospecting purposes only and not for the purpose of obtaining minerals for use or sale; provided that—
   (i) not more than 20 persons are employed in or about such excavation;
   (ii) no part of the excavation extends beneath the superjacent ground; and
   (iii) the depth of the excavation measured from its highest to its lowest point nowhere exceeds 20 feet or, in the case of an excavation for coal, 50 feet.
4. Iron ore mines worked without mechanical power, the whole ore from which is supplied locally to village smelters and blacksmiths.
5. Certain other specified mines for coal, stone, clay, and salt.

Although designed primarily to maintain health and safety in mines, the Indian Mines Act and Regulations provide for the collection of statistics from mines which come within the Act.

TABLE 9.

FORM VIII (see Regulation 3). (For all mines except mica mines.)

Output for year ending on the 31st December, 19 .

Name of mineral raised, and metal (if any) extracted.	Total amount of mineral raised. The figures should be stated— (*a*) in the case of gem-stones, in carats; (*b*) in the case of alum, amber, asbestos, graphite, jadestone, steatite, tin ore, tungsten ore, in cwts. or where the circumstances require greater particularisation in order to give an accurate estimate of small outputs, in cwts and lbs. Output of radio-active minerals and rare minerals such as molybdenite, monazite pitchblende, samarskite, tantalite, triplite, should be returned in cwts. and lbs. (*c*) in the case of clay, limestone, magnesite, marble, phosphatic rock, salt, slate, and other stone, and all metalliferous ores except those referred to in (*b*), in tons.	Total value at the mine of mineral raised. ('Value' means and should be calculated upon actual or estimated selling price at the mine). Any charges incurred in transporting the mineral outside the mine property should not be included.	Quantity of metal or metals extracted at the mine. Each metal should be shown separately— (*a*) in the case of gold, silver and other precious metals, in troy ounces; (*b*) in the case of tin in cwts.; (*c*) in the case of other metals in tons and fractions of tons.	Value of metal or metals extracted at the mine. The value of each metal should be shown separately.
1	2	3	4	5
TOTAL:				

Signature of Owner, Agent or Manager
(If the form is signed by a Managing Agent the words 'for owner' should be added.)
Date of signature.

Each mine must prepare returns on standard forms, which are forwarded to the Chief Inspector of Mines. These returns contain particulars of production, labour employed, power supply, explosives, machinery, accidents, prosecutions, and epidemic diseases.

Statistics of production are particularly important to those interested in the industry, as they are the means by which the general trend of business may be judged. It is important, therefore, that this information should be accurate and complete. The forms used for submitting returns on production in India, for mines working within the Mines Act, are shown in Tables 9, 10, and 11.

Mines which do not come within the Mines Act are now also required to submit returns of production to the local revenue officer, in the form shown in Table 12.

TABLE 10.

FORM VII (see Regulation 3). (For mica mines only.)

Output for year ending on the 31st December, 19

Total amount of dressed mica raised.	Total amount of dressed mica consigned.	Total value at the mine of mica consigned ('Value' means and should be calculated upon actual or estimated selling price at the mine. Any charges incurred in transporting the mica outside the mine should not be included).
1	2	3
Cwts. Lbs.	Cwts. Lbs.	

Signature of Owner, Agent or Manager.

(If the form is signed by Managing Agents the words 'for owner' shall be added.)

Date of signature.

TABLE 11.

FORM VIII (see Regulation 3 (2)).

Output for year ending on the 31st December, 19 .

	Opening stocks on 1st January, 19 .	Raisings (including colliery consumption and coal used for coke-making)	Total value of raisings ('Value' means, and should be calculated upon actual or estimated selling price into wagons at the mine).	Total of columns 2 and 3.	Despatches	Colliery consumption (exclusive of coal used for coke-making).	Coal delivered for coke on colliery	Closing stocks on 31st December, 19 .	Total of columns 6, 7, 8 and 9.
1	2	3	4	5	6	7	8	9	10
	Tons	Tons	Rs.	Tons	Tons	Tons	Tons	Tons	Tons
Coal including rubble stock and dust ..	..	..	..	..	..	..	..	..	..

Coal despatched to coke factories. Tons

NOTE.—The total in column 5 must be the same as the total in column 10.
The figures should be in tons and rupees, omitting cwts. and annas.

	Opening stocks.	Coke made.	Total of columns 1 and 2.	Coke despatched.	Colliery consumption.	Closing stocks.	Total of columns 4, 5 and 6.	Total value of coke made ('Value' means, and should be calculated upon actual or estimated selling price into wagons at the mine).
	1	2	3	4	5	6	7	8
	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Rs
Coke (hard) ..	..	..	..	..	..	..	..	..
Coke (soft) ..	..	..	..	..	..	..	..	..

NOTE.—The total in column 3 must be the same as the total in column 7.
The figures should be in tons and rupees, omitting cwts. and annas

Signature of Owner, Agent or Manager.
(If the form is signed by Managing Agents the words 'for owner' should be added.)
Date of signature.

TABLE 12.

Statement showing the production of minerals in mines which do not come under the provisions of the Indian Mines Act.

Name and/or number of mine or pit, quarry or excavation, and locality (village).	Name of mineral, ore, stone, or clay, or related substance worked and/or prepared.	OUTPUT DURING 19		AVERAGE NUMBER OF PERSONS EMPLOYED DAILY.				
		Quantity of each quality or grade sold separately.	Value at pit's mouth of each quality or grade.	Men.		Women.	Children.	Total.
				Above ground.	Below ground.			

Certified that particulars for mines regulated by the Indian Mines Act, 1923, have been excluded from the above statement.

Collector or Deputy Commissioner..................

Notes and Instructions :—

1. The output should be given—
   (*a*) in troy ounces in the case of gold;
   (*b*) in carats in the case of gem stones;
   (*c*) in cwts.—or in cwts. and lbs. where the circumstances require greater particularisation in order to give an accurate estimate of small outputs,—in the case of alum, amber, asbestos, chromite, corundum (not being gem corundum), graphite, jadestone, mica, steatite and tin ore; and
   (*d*) in tons, in the case of clays, iron ore, limestone, magnesite, manganese ore, other unspecified metalliferous ores, salt and slate.
2. The total amount of mineral raised during the year should be given.
3. The value of the mineral given should be based on the actual or estimated wholesale price of the mineral at the pit's mouth.
4. The average number of persons employed daily should be obtained by dividing the aggregate number of daily attendances (permanent and temporary) by the number of working days.
5. Every person of or above the age of fifteen years should be entered as an adult.

That there are deficiencies in these returns may be suspected. Perhaps the most striking example is in the case of mica; the export figures of mica over a prolonged period of years have been as much as 50% greater than the production figures as given in returns to the Chief Inspector of Mines. In the case of mica, the industry accepts the export figures as a more correct guide to the general trend of trade, but other minerals marketed locally cannot be so readily checked. The submission of a false return may result in a fine of five hundred rupees or imprisonment up to three months, whilst the submission of no returns may result in a fine of two hundred rupees.

The 'estimated' pit's mouth valuation may be liable to variations depending entirely on the whim of the mine owner or manager. It would be preferable if the following details were also required in these returns:—

(*a*) Amount of mineral despatched from the mine, or sold.
(*b*) Actual sale price.
(*c*) Transport and other despatch costs from mine up to place of sale.

Mica returns are for dressed mica, yet there are very few mines indeed on which the mica is actually dressed at the mine. The crude mica is brought to godowns at a distance from the mine lease.

In Table 9, the return requires the quantity of metal extracted at the mine. There are few mines indeed at which a metal could be extracted at the site of the mine within the mine lease. At some mines, mineral may be despatched from the mine either crude, or dressed.

CHAPTER XXI

TAXATION AND TARIFFS

There is a tendency amongst part of the mining community to regard royalties and rents as taxes on the industry, comparable with income tax or other explicitly recognised taxes. Of course, ultimately, any tax payment is simply the price paid for State service. Royalty is certainly not a tax in the sense of being a payment for State service of a general nature; on the contrary it is nothing more nor less than the actual price paid for the purchase of a raw material. The surface rent paid for a mineral lease is equivalent in every way to the rent paid for the occupation of any other form of property.

As in industry in general, mining profits are subject to income tax. In the calculation of mining profits the distinction between revenue expenditure and capital expenditure is liable to various interpretations; from time to time mine owners have been forced to object to rulings by Income Tax Commissioners on the distinction between revenue and capital expenditure. These objections, which have frequently been legitimate, have been made necessary by the fact that Income Tax Officers are not familiar with the technique of mining and have sometimes regarded certain items of expenditure from the point of view of secondary industries. Unlike the latter, mining is based on the extraction of a depleting asset which, once removed, can never be renewed.

Mining operations may be divided into (*a*) making a mine, and (*b*) working a mine. The former includes expenditure on adits, shafts, inclines, crosscuts, levels, winzes and rises, which are first necessary to open up the deposit, create reserves, and permit of haulage of the mineral to the surface; before any mineral is actually produced, large sums may be expended on development work in this way, and such capital expenditure is entitled to depreciation allowance as in the case of expenditure on plant and buildings. In order to maintain the reserves at the minimum figure during the

working of the deposit, and also to keep up the rate of production, mineral must continue to be blocked out by further development work, and the cost of this work is certainly an item of revenue expenditure. But, where capital expenditure ends and revenue expenditure begins, in development, is a point which the layman has difficulty in appreciating.

It would be of advantage to the mining industry if such matters could be referred to a recognised technical arbitration committee, which would act in an advisory capacity to the income-tax authorities, whenever necessary.

Such taxes as Excess Profits have also a different bearing in mining than in other industries. Any single deposit has only a definite quantity of mineral, and can be exhausted in say, one, ten, or twenty years according to the rate of working. Hence the profits may be distributed over one, ten, or twenty years as the case may be; thus, a mine which is worked slowly with no increase in profits in any one year, and therefore pays no Excess Profits Tax, will ultimately make far greater profits than a mine which is worked out in a short time, perhaps under the stress of national effort, and the profits from which are mostly absorbed by Excess Profits Tax. The question is a difficult one, but, in mining, a tax based on increased profit spread per unit of mineral, accruing from *increased prices,* would certainly be more equitable than one based on total increased profit associated with the more rapid exhaustion of assets.

The mining industry may have other forms of taxes levied on it for various purposes. For example, the Bihar coal industry has to pay a cess to maintain the activities of the Mining Board, and an excise duty on coal for the maintenance of rescue stations. It has been estimated that the additional taxes in various forms total about 7 annas per ton of coal in Bihar. In some cases the mineral industry may be well able to afford such additional taxation, but the imposition of further taxes may even go so far as to destroy particular industries. The trade in some minerals has remarkably wide ramifications and may be affected by conditions in widely distant parts of the world; these facts must be appreciated whenever taxation in any guise is under consideration.

Mines have not as yet been subject to a property tax based on the value of the mineral deposit. Should this ever be attempted in the future, a far more complete technical valuation of mines will be necessary than is now possible from the present system of mineral returns.

The mineral industry has from time to time received protection from the Central Government in the form of tariff on imports. Of course such a tariff may rest heavily on the local consumer, but, in the case of the iron and steel trade particularly, it has led to the development of an enormous industry which can now undersell overseas manufacturers. Some mineral industries, for example, copper mining and smelting, must be maintained indefinitely by tariff protection, otherwise they could not hope to compete with producers in other countries which have vast resources with low treatment costs. These industries may be so important to India that they cannot be permitted to languish or be extinguished by overseas competition, and the amount of tariff is little enough to pay for the security of such vital industries. The consumer may argue, however, that a subsidy is fairer to him than a tariff. Questions of this nature, particularly whether tariff protection to indigenous industries is more valuable in the long run to the country than cheap imported materials, provide scope for prolonged discussion by economists and politicians.

CHAPTER XXII

SOME LEGAL ASPECTS

The greatest legal decision yet to be made concerning minerals in India is whether mineral rights in permanently settled estates rest with the zamindars or with Government. Zamindars have been permitted, without direct objection on the part of Government, to issue mining leases within their land. As yet Government has not put forward, as a test case, any claim inconsistent with the rights which have for so long been assumed and declared by zamindars—to date, such cases as have been decided have been between zamindars and tenure holders and not between Government and zamindars.

From time to time the legal fraternity has expressed views on one side or the other. The whole discussion has been well summarised recently by A. N. Sinha (*Madras Law Journal*, 1941—I). Should there be any attempt at reversion of the present position of zamindars it will certainly entail a revolution in accepted rights amounting almost to a national upheaval! The present writer does not presume to enter the discussion on the intention of the Permanent Settlement—even if the Permanent Settlement had any thought to mineral rights, which seems doubtful; the arguments which enter into the discussion are entirely legal in character and require no technical interpretation. But the persistence of the present practice does carry technical implications which are of importance, and are independent of the legal niceties involved.

The Bengal Land Revenue Commission, under the chairmanship of Sir Francis Floud, in its majority report of 1940 drew attention to the desirability of Government acquiring the mining rights in permanently settled areas. There is no doubt that, from the point of view of the State, the continuation of mineral rights vested in zamindars is not advantageous in conserving the country's mineral resources, and is not to the ultimate advantage of future

industrial development. The best boundaries for a mining lease in which, say, coal seams are to be efficiently mined, are not always identical with the zamindary boundaries. Zamindars cannot invariably be expected to have the long term outlook of Government, and may impose lease terms which may provide immediate large increases of income but to the detriment of the most efficient methods of removal of the mineral resources. Zamindars may also sell their mineral rights, either in total or in part, and litigation, or even total preclusion of mineral development, has in some cases been caused by rival claimants to the mineral rights. However, perhaps the most serious obstruction to mineral development is to be found in those zamindaries which are under joint ownership, where any one of the partners can refuse the grant of a mining lease and prevent development of the contained minerals. Such cases give rise to almost endless litigation which may not always be successfully terminated by partition of the estate. Partition may require valuation, and the difficulties involved in this will be readily appreciated from chapter XVII of this book—the writer was recently amazed to learn that such a task of mineral valuation had been placed in the hands of a lawyer! With all respects to the general ability of the legal profession, and in particular to its attention to legal detail, it is not competent to undertake an essentially technical task such as mineral valuation; in such a task it should recognise its limitations and call upon the assistance of colleagues of the mining profession.

A fruitful source of litigation from time to time is the definition of the term 'mineral'. The technical definition of the word is given in chapter I, and it will be noted that the definition implies precise economic restrictions which are by no means academic, as they possess, or should possess, a definite legal significance. The legal profession has by no means always appreciated the economic factors incorporated in the definition of the term mineral—'market value' and 'expectations of profitable disposal'—but has even given greater weight to niceties of legalistic argument as to whether a substance is of sufficiently common occurrence in a neighbourhood as to exclude it from the ambit of those supposedly select legal

minerals to which alone the principles of mineral rights apply. Consequently, in litigation on royalty payments, legal definitions have at times appeared which may be at variance with the mining definition, but which the author has failed to appreciate. Preciseness of legal interpretation may overrule the commonsense of obvious intention, notwithstanding that the search for the latter is generally understood to be the ultimate aim of legal discussion.

These observations prompt an advice which all prospective lessees and lessors of land property, for any purpose whatever, would do well to follow. Every lease agreement should state whether or not any material may be excavated from the surface or from under the surface, and may be removed from the lease. Where removal of any mineral material is permissible, whether it be soil, gravel, rock, ore, or any other form of mineral aggregate, and which is to be used for any purpose whatever elsewhere, then the lease agreement should state explicitly whether royalty is or is not to be paid on this material, or state that rent is to be regarded as payment in lieu of royalty.

There is no legal objection to separate leases being granted over the same area to two or more lessees for the mining of different minerals in separate deposits. In some cases the mining operations on the various minerals may be so entirely different that such a procedure is advisable. For example, a copper smelting company may have the lease of a certain area for copper ore; the same area may contain beds of quartz-schist which a steel company may wish to excavate for lining Bessemer converters. However, before a second lease is granted over the same area for a different mineral technical opinion should be sought, for ultimately the second mining operations may interfere with the first; indeed, the second mineral may later be found to occur in the same deposit as the first, in which case both lessees may have a claim on it. As a general rule the leasing of the same area to different lessees for different mining purposes should be avoided.

The writer has read through many mineral leases and, although the majority are sound enough, some have been couched in terms of legalistic phraseology difficult for the layman to comprehend,

perhaps also displaying an ignorance of technical mining terminology and mining requirements. No profound legal knowledge would be needed for a competent mining engineer or geologist 'to drive a coach and four' through such leases. Perhaps the fault does not rest entirely with the legal drafter of the lease, for the technical profession is by no means free from jargon and may be equally ignorant of legal diction. It does, however, suggest the wisdom of submitting mining leases to competent mining men for comment, and perhaps of even greater importance, the advisability of simplifying legal phraseology. Perhaps there is scope here in India for mining engineers who wish to transfer their activities to the legal profession.

CHAPTER XXIII

EXPANSION OF THE MINERAL INDUSTRY IN INDIA, AND STATE AID

India's mineral assets in terms of area and not of population are comparable with those of other countries. Up to 1939, the development of the mineral industry had not been particularly backward, and production of minerals had not lagged far behind the market's capacity for absorption—indeed, in some cases there had been a tendency to overproduction. Mistakes in the mining and treatment of minerals have been made in the past, as in other countries, but concerns like the Indian Copper Corporation and the Tata Iron and Steel Company are as efficient as any in the world, with staffs constantly seeking improved methods of working. This has been the position in the past, development during the present war may not be discussed here, but suggestions as to future directions of progress and expansion may be of interest.

At least four minerals mined in India—mica, ilmenite, monazite, and manganese ore—are of great importance to world industries, and large amounts of them have been exported and must continue to be exported. Exports of mica have been almost entirely of unmanufactured mineral, whilst ilmenite and manganese have been shipped entirely as raw material. There is no reason why India should not develop an extensive micanite industry, using mica splittings, or a titanium oxide industry from ilmenite, or manufacture thoria and cerium from monazite, or export much of her manganese in the form of ferromanganese. There are no attendant technical difficulties that cannot be readily overcome in this country, the only problem to be faced would be in prevailing upon the overseas market to accept the Indian manufactured material.

India's resources of iron ore are so vast that export of ore will always be advisable whenever a market is available. At the same time there remains scope for the expansion of the iron and steel

industry not only to supply the whole of the domestic market, but also for the export of iron and steel whenever possible in lieu of ore.

There are many materials imported into India which could be manufactured in this country from the mineral raw materials available. Several lines of development are indicated below.

For the manufacture of such natural abrasives as silicon carbide and fused alumina adequate raw materials are available in the country. Such natural abrasive and polishing media as silica, garnets, corundum, lime, talc and magnesia could certainly be treated in the country both for domestic use and export.

The development of an aluminium industry is already in hand. India's resources of aluminium ore, bauxite, are such that this country is likely to be one of the most important producers of aluminium in the future. Should this prove correct titanium oxide and vanadium oxide will be important by-products.

The barite deposits available may be more vigorously developed, not only for the manufacture of lithopone to be used in India's growing paint industry but also for the production of various barium salts.

The chromite resources of India are of such importance that the application of the mineral in industries other than refractories is desirable. The manufacture of ferrochrome for use in special alloys will undoubtedly expand, as also will the development of a chromium chemical industry for the manufacture of bichromate and other salts used in tanning, dyeing, paints, etc.

There is already quite a considerable firebrick, stoneware, tile, and pottery industry in India, and this is gradually expanding with the market demand. The manufacture of high grade pottery is restricted to some extent by the comparative lack of high grade china clays, but it is not at all improbable that if the industry were willing to pay a higher price for its clays it may be possible by research to improve considerably many of the present poorer quality clays. The same remarks apply also to white clays used in textile and paper industries. Other special clays, such as bentonite and fullers earth, will be in greater demand as other industries expand.

The coal industry has been of the utmost importance to India. Increase in production is not so desirable as improvements in the methods of production and marketing, which will lead to the conservation of the limited reserves available, particularly of coking coals. There is also great scope for the better utilisation of this important fuel, and for the production of innumerable by-products vital to the development of other industries. Much has been written during the last twenty years on what should be done in order to develop this industry on more rational lines, and there is the talent available in the country to undertake all that is required, but, apart from the improvements of a few leading firms, progress has been tardy. To those who view nationalisation of the mineral industry with disfavour the trend of the coal industry today leads to doubts whether nationalisation would not, after all, be in the country's best interests.

Although further deposits of copper, such as those in Jaipur and Darjeeling, may be worked in the future, the margin of profits in normal times is small, and copper mining is likely to remain an anxious undertaking. Without an import tariff it would not be payable.

Fluorite resources in India are small, and confined so far as we know to Khairagarh and Nandgaon States. The utilisation of the mineral for the manufacture of artificial cryolite (vital to aluminium production) and of hydrofluoric acid would appear as desirable as its application as a flux in steel smelting.

Research on the raw materials for glass manufacture has become increasingly energetic in recent years and will undoubtedly give valuable results. The glass industry is gradually expanding and will continue to expand, as imports are far in excess of the domestic production. Increased output of the better quality glasses is eminently desirable, and the production of optical glass would assist the firm establishment of an optical instruments industry independent of any imported parts.

The discovery of deposits of gold comparable with those of Kolar in other parts of India does not appear to be hopeful. The limits of depth to which the Kolar mines can be worked will depend

on the gold content and the engineering difficulties to be surmounted at increased depth.

There are considerable resources of gypsum in India, utilisation of which has only recently commenced. Apart from its application in cement and plasters, and as a filler, etc., gypsum is likely to be the most important future source of sulphur and sulphuric acid, which are so important to chemical industry in general; it may be urged that this line of development should be pursued energetically.

The expansion of the iron and steel industry may be safely left in the hands of the present competent companies. It is to be hoped, however, that the production of ferroalloys will increase up to the market's capacity for absorption; several of the special raw materials required are available in the country.

Attempts should be made to utilise more widely in India the excellent kyanite and sillimanite deposits available, not only for refractory bricks in glass-melting furnaces, but also for special porcelains. The high price of the raw material has been the main obstacle to the use of kyanite in refractories in India.

Should the development of the lead-zinc deposits of Zawar, in Mewar State, Rajputana, prove successful a very useful quota will be added to India's raw materials. Small deposits reported from time to time elsewhere in India have not been of importance.

The cement industry has made enormous strides in recent years and will presumably continue to develop. The use of lime for chemical purposes is capable of great expansion: the demand for such materials as bleaching powder, calcium carbide and cyanamid are likely to increase.

The magnesite industry, for the manufacture of refractories, is firmly established. The excellent magnesite of South India should be ideal for the smelting of metallic magnesium, utilising calcium carbide manufactured in the country and other fluxes on which research is necessary. There is no reason why India should not be one of the world's important producers of metallic magnesium.

Manganese ore in India is of such excellent quality that there is considerable scope for expanded application in domestic industry.

The manufacture of dry batteries, containing local manganese ore, has become quite an important although small industry. The development of a manganese chemical industry may also be expected. It is not at all improbable that much of the present export of manganese ore could be replaced by ferromanganese. The increasing local production of special manganese steel and other alloys is also desirable. Research in the improvement of ore quality by mechanical means may give valuable results.

Mica is one of the most important of India's exports. The export of block mica must continue, but there is no reason why the greater part of the condenser films now exported should not be cut to shape in this country. The manufacture of micanite in various forms, at present in its infancy, will undoubtedly expand, and in the future with increased skill and general efficiency it is not entirely improbable that the greater part of the mica splittings may be converted into micanite locally. The increased use of ground mica made from scrap may also be expected in India—there is possibly scope here for considerable research.

The paint industry in India is gradually expanding, and the country's resources in mineral pigments will be slowly developed as required. Methods of improvement in quality of the raw materials may require attention in order to maintain the rigid standards now demanded by paint consumers. India has the mineral raw material for perhaps the most valuable of all paint and lacquer bases, titanium dioxide.

Scattered throughout the Indian Peninsula there are innumerable mineral springs. Recent investigation of some of these waters has demonstrated that they possess valuable medicinal properties, and as other springs are examined there is little doubt that they, too, will be found to possess similar properties. The use of these springs as spas and for bottled mineral waters should certainly command greater attention in the near future.

In other countries the manufacture of mineral wool from molten rock or from metallurgical slag has become quite an important industry. As Indian industry expands in various directions, and the standard of living also improves, there will be a great demand

for insulating material of this type. It is not at all improbable that if the manufacture of this material were commenced immediately, it would quickly be accepted as a standard insulating material in buildings, if accompanied by the requisite publicity.

Monazite, which is now exported for the extraction of thoria and cerium, could undoubtedly be treated in this country. The domestic market for thoria and cerium is small, however, and it would still be necessary to find a market overseas for these products.

Surface indications of petroleum have been very thoroughly examined in India, but results have been disappointing. Intensive exploration on a wide scale of potentially productive areas, using geophysical equipment, will be continued in the future.

The phosphate deposits of Singhbhum have certainly been neglected in recent years, and deserve attention. It seems remarkable that they have not been required either for agricultural or metallurgical purposes, whilst their possible chemical use may also receive consideration.

India has no such extensive natural deposits of potassium salts as are to be found in Europe and America, but it is not improbable that future research may provide an economic means of extracting potash from the widespread deposits of feldspar. In other countries potash is recovered from blast furnace and cement kiln flue dust; there is practically no recoverable potash in Indian blast furnace flue dusts. Research on other flue dusts may possibly yield useful results.

A certain amount of salt is still imported into India. The industry is capable of expansion, more especially for the manufacture of such sodium compounds as soda ash and salt cake. The residual bitterns also should receive more attention for the extraction of potash and magnesium chloride, and even perhaps also for bromine and iodine.

Excellent deposits of steatite (talc) are available in India, capable of supplying any demand for refractory material or for acid-resisting tanks and slabs, or for powder to be used as filler or

as a polishing medium, or for cosmetics, etc. As the market demand for these increases so will production.

Although a certain amount of sulphur is available from the natural sulphur deposits of Baluchistan, and from one or two small deposits of pyrite, besides also from the flue gases at the copper smelters in Singhbhum, the important future source of the element, and of sulphuric acid, will be the gypsum deposits, particularly those of the Salt Range.

It is unfortunate that, to date, the entire ilmenite production of India has been exported instead of being manufactured into titanium white in the country. The manufacture of ferrotitanium alloys and of special titanium compounds for various purposes should not be beyond India's technical capacity in the near future.

India's tungsten production is never likely to be great, but should be capable of supplying her own ferrotungsten requirements for some years, and the local manufacture of tungsten carbide may be possible.

With the manufacture of ferro-alloys in India the vanadium-bearing titaniferous iron ores of Singhbhum and Mayurbhanj are certain to be developed. Actual consumption of vanadium is quite small, however, and as India's own requirements would be normally of the order of 100 tons annually, attempts at finding an overseas market would be advisable. In competition with such producers as Peru, Northern Rhodesia, and the United States, success in exporting would be doubtful.

The possibility of a zinc industry in India is dependent entirely on the success of the Zawar lead-zinc mines in Rajputana.

The above suggestions illustrate the scope for future expansion in India. Immediate expansion in all directions should not be expected, indeed it may be desirable to retard the actual mining of certain deposits until related industries can be built up which are capable of absorbing such minerals locally for wider and more important purposes.

Industries have tended to segregate more particularly into Bihar and Bengal, largely because of the available coal. It is to be

hoped that future manufacturing centres will be more widely scattered over the country. For example, should it be possible to develop suitable metallurgical coke from the coals of the Central Provinces or Central India, there is no reason why an iron and steel industry should not be created in the Central Provinces. Those provinces which desire to attract industries should endeavour to provide the necessary cheap power, even if the attendant financial risk is considerable.

In India small producers not uncommonly have difficulty in finding a market for their minerals, and manufacturers sometimes are unable to obtain small parcels of materials although these may be available in the country. Some cooperative form of marketing or a Mineral Exchange would undoubtedly be useful. In a country like India the producer tends to be at the mercy of the consumer, and the prices of many mineral raw materials are sometimes at an absurdly low figure. A Mineral Exchange may be of value in stabilising prices of minerals in various parts of the country.

In the future development of India's mineral resources Government assistance is, of course, desirable.

If minerals are to be mined and utilised with the greatest efficiency, Government officials should use discretion in the allocation of mineral leases; the small miner with little capital should be discouraged except in the case of small deposits requiring little capital, such as clay, building stones, road metal and railway ballast. Concerns with sufficient capital to develop the deposits efficiently should be given every encouragement.

This discrimination may be carried even further with a view to encouraging the use of minerals in the country. For example, it would be preferable to reserve all the manganese deposits of Singhbhum and the adjacent Orissa States for the Indian iron and steel trade, as these deposits are the most accessible to the steel works, leaving the Central Provinces and other ores for the export trade.

The collection and publication of reliable statistics concerning all phases of the industry is essential if the country's mineral

production and utilisation is to expand on sound lines. Anticipations of immediate and distant future requirements are dependent on such information. Returns of mineral production from all mines throughout India should be collected in detail, not only in areas leased by the provincial Government and in zamindari mines, but also in Indian States. Some of the returns at present submitted are not sufficiently precise to be of value, particularly statements of pit's mouth values.

In India, excellent research institutes have been founded to assist various industries such as agriculture, forestry, and jute. It is indeed paradoxical that India's mineral industry, which forms the real foundation for the country's industrial expansion, should have received no assistance of this nature. The scope for a Mineral Research Institute, controlled by practical men of experience, is enormous. Such an Institute would investigate many lines of mineral enquiry, and would also help to coordinate the various problems of different branches of the industry. Improvements in treatment of one kind of mineral are commonly related to improvements in treatment of another. For this reason it would be preferable to include the Fuel Research Station, which has so long been advocated, within the Mineral Research Institute. Such an Institute would include also a Bureau of Mineral Information which would serve as a centre for the dissemination of information regarding minerals, and would issue statistics and bulletins; it would have a permanent staff whose duty it would be to make a study of Indian economic mineral resources. The Institute would be in close cooperation both with industry in general and with Government; its success would be largely dependent on the selection of its administrative staff from technical men of wide experience, who must be left to work without political or official interference.

The provinces have now taken over the administration of their mineral rights. It is obvious that the mineral industry of one province is dependent also on industry in other provinces; the problem of development is concerned with all India and not with individual provinces or States. One cannot but deprecate

the increasing tendency to think provincially, for only by tackling mineral problems in a national way is it possible for the maximum value to be obtained from our resources. At the moment it is, perhaps, futile to discuss future world policy, but it is possible to entertain hopes beyond even the national sphere, and to look forward to the time when nations will consent to frame an international policy for the coordinated and rational utilisation of mineral resources throughout the world.

VALUATION TABLES

TABLE 13.

I^n or $(1+i)^n$

The amount of Re1 in n years at the following rates percent compound interest.

Years.	2½ %	3 %	3½ %	4 %	4½ %	5 %	6 %	7 %
1	1·0250	1·0300	1·0350	1·0400	1·0450	1·0500	1·0600	1·0700
2	1·0506	1·0609	1·0712	1·0816	1·0920	1·1025	1·1236	1·1449
3	1·0769	1·0927	1·1087	1·1249	1·1412	1·1576	1·1910	1·2250
4	1·1038	1·1255	1·1475	1·1699	1·1925	1·2155	1·2625	1·3108
5	1·1314	1·1593	1·1877	1·2167	1·2462	1·2763	1·3382	1·4026
6	1·1597	1·1941	1·2293	1·2653	1·3023	1·3401	1·4185	1·5007
7	1·1887	1·2299	1·2723	1·3159	1·3609	1·4071	1·5036	1·6058
8	1·2184	1·2668	1·3168	1·3686	1·4221	1·4775	1·5938	1·7182
9	1·2489	1·3048	1·3629	1·4233	1·4861	1·5513	1·6895	1·8385
10	1·2801	1·3439	1·4106	1·4802	1·5530	1·6289	1·7908	1·9672
11	1·3121	1·3842	1·4600	1·5395	1·6229	1·7103	1·8983	2·1049
12	1·3449	1·4258	1·5111	1·6010	1·6959	1·7959	2·0122	2·2522
13	1·3785	1·4685	1·5640	1·6651	1·7722	1·8856	2·1329	2·4098
14	1·4130	1·5126	1·6187	1·7317	1·8519	1·9799	2·2609	2·5785
15	1·4483	1·5580	1·6753	1·8009	1·9353	2·0789	2·3966	2·7590
16	1·4845	1·6047	1·7340	1·8730	2·0224	2·1829	2·5404	2·9522
17	1·5216	1·6528	1·7947	1·9479	2·1134	2·2920	2·6928	3·1588
18	1·5597	1·7024	1·8575	2·0258	2·2085	2·4066	2·8543	3·3799
19	1·5987	1·7535	1·9225	2·1068	2·3079	2·5270	3·0256	3·6165
20	1·6386	1·8061	1·9898	2·1911	2·4117	2·6533	3·2071	3·8697
21	1·6796	1·8603	2·0594	2·2788	2·5202	2·7860	3·3996	4·1406
22	1·7216	1·9161	2·1315	2·3699	2·6337	2·9253	3·6035	4·4304
23	1·7646	1·9736	2·2061	2·4647	2·7522	3·0715	3·8197	4·7405
24	1·8087	2·0328	2·2833	2·5633	2·8760	3·2251	4·0489	5·0724
25	1·8539	2·0938	2·3632	2·6658	3·0054	3·3864	4·2919	5·4274
26	1·9003	2·1566	2·4460	2·7725	3·1407	3·5557	4·5494	5·8074
27	1·9478	2·2213	2·5316	2·8834	3·2820	3·7335	4·8223	6·2139
28	1·9965	2·2879	2·6202	2·9987	3·4297	3·9201	5·1117	6·6488
29	2·0464	2·3566	2·7119	3·1187	3·5840	4·1161	5·4184	7·1143
30	2·0976	2·4273	2·8068	3·2434	3·7453	4·3219	5·7435	7·6123
35	2·3732	2·8139	3·3336	3·9461	4·6673	5·5160	7·6861	10·6766
40	2·6851	3·2620	3·9593	4·8010	5·8164	7·0400	10·2857	14·9745
45	3·0379	3·7816	4·7024	5·8412	7·2482	8·9850	13·7646	21·0025
50	3·4371	4·3839	5·5849	7·1067	9·0326	11·4674	18·4202	29·4570

TABLE 13.—(*Contd.*)

I^n or $(1+i)^n$

The amount of Re1 in n years at the following rates percent compound interest.

Years	8%	9%	10%	12%	15%	20%	25%
1	1·0800	1·0900	1·1000	1·1200	1·1500	1·2000	1·2500
2	1·1664	1·1881	1·2100	1·2544	1·3225	1·4400	1·5625
3	1·2597	1·2950	1·3310	1·4049	1·5209	1·7280	1·9531
4	1·3605	1·4116	1·4641	1·5735	1·7490	2·0736	2·4414
5	1·4693	1·5386	1 6105	1·7623	2·0114	2·4883	3·0518
6	1·5869	1·6771	1·7716	1·9738	2·3131	2·9860	3·8147
7	1·7138	1·8280	1·9487	2·2107	2·6600	3·5832	4·7684
8	1·8509	1·9926	2·1436	2·4760	3·0590	4·2998	5·9605
9	1·9990	2·1719	2·3579	2·7731	3·5179	5·1598	7·4506
10	2·1589	2 3674	2·5937	3·1058	4·0456	6·1917	9·3132
11	2·3316	2·5804	2·8531	3·4785	4·6524	7·4301	11·6415
12	2·5182	2·8127	3·1384	3·8960	5·3503	8·9161	14·5519
13	2·7196	3·0658	3·4523	4·3635	6·1528	10·6993	18·1899
14	2·9372	3·3417	3·7975	4·8871	7·0757	12·8392	22·7374
15	3·1722	3·6425	4·1772	5·4736	8·1371	15·4070	28·4217
16	3·4259	3·9703	4·5950	6·1304	9·3576	18·4884	35·5271
17	3·7000	4·3276	5·0545	6·8660	10·7613	22·1861	44·4089
18	3·9960	4·7171	5·5599	7·6900	12·3755	26·6233	55·5112
19	4·3157	5·1417	6·1159	8·6128	14·2318	31·9480	69·3889
20	4·6610	5·6044	6·7275	9·6463	16·3665	38·3376	86·7362
21	5·0338	6·1088	7·4002	10·8038	18·8215	46·0051	108·4202
22	5·4365	6·6586	8·1403	12·1003	21·6447	55·2061	135·5253
23	5·8715	7·2579	8·9543	13·5523	24·8915	66·2474	169·4066
24	6·3412	7·9111	9·8497	15·1786	28·6252	79·4968	211·7582
25	6·8485	8·6231	10·8347	17·0001	32·9190	95·3962	264·6978
26	7·3964	9·3992	11·9182	19·0401	37·8568	114·4755	330·8723
27	7·9881	10·2451	13·1100	21·3249	43·5353	137·3706	413·5903
28	8·6271	11·1671	14·4210	23·8839	50·0656	164·8447	516·9879
29	9·3173	12·1722	15·8631	26·7499	57·5755	197·8136	646·2349
30	10·0627	13·2677	17·4494	29·9599	66·2118	237·3763	807·7936
35	14·7853	20·4140	28·1024	52·7996	133·1755	590·6682	2465·1903
40	21·7245	31·4094	45·2593	93·0510	267·8635	1469·7716	7523·1639
45	31·9204	48·3273	72·8905	163·9876	538·7693	3657·2620	22958·8740
50	46·9016	74·3575	117·3909	289·0022	1083·6574	9100·4381	70064·9322

TABLE 14.

$$\frac{1}{I^n} \text{ or } \frac{1}{(1+i)^n}$$

Present value of Re 1, payable n years hence, interest calculated at the following rates percent compound interest.

Years.	2½%	3%	3½%	4%	4½%
1	·9756	·9709	·9662	·9615	·9569
2	·9518	·9426	·9335	·9246	·9157
3	·9286	·9151	·9019	·8890	·8763
4	·9060	·8885	·8714	·8548	·8386
5	·8839	·8626	·8420	·8219	·8025
6	·8623	·8375	·8135	·7903	·7679
7	·8413	·8131	·7860	·7599	·7348
8	·8207	·7894	·7594	·7307	·7032
9	·8007	·7664	·7337	·7026	·6729
10	·7812	·7441	·7089	·6756	·6439
11	·7621	·7224	·6850	·6496	·6162
12	·7436	·7014	·6618	·6246	·5897
13	·7254	·6810	·6394	·6006	·5643
14	·7077	·6611	·6178	·5775	·5400
15	·6905	·6419	·5969	·5553	·5167
16	·6736	·6232	·5767	·5339	·4945
17	·6572	·6050	·5572	·5134	·4732
18	·6412	·5874	·5384	·4936	·4528
19	·6255	·5703	·5202	·4746	·4333
20	·6103	·5537	·5026	·4564	·4146
21	·5954	·5375	·4856	·4388	·3968
22	·5809	·5219	·4692	·4220	·3797
23	·5667	·5067	·4533	·4057	·3634
24	·5529	·4919	·4380	·3901	·3477
25	·5394	·4776	·4231	·3751	·3327
26	·5262	·4637	·4088	·3607	·3184
27	·5134	·4502	·3950	·3468	·3047
28	·5009	·4371	·3817	·3335	·2916
29	·4887	·4243	·3687	·3207	·2790
30	·4767	·4120	·3563	·3083	·2670
35	·4214	·3554	·3000	·2534	·2143
40	·3724	·3066	·2526	·2083	·1719
45	·3292	·2644	·2127	·1712	·1380
50	·2909	·2281	·1791	·1407	·1107

TABLE 14.—(*Contd.*)

$$\frac{1}{I^n} \text{ or } \frac{1}{(1+i)^n}$$

Present value of Re1, payable n years hence, interest calculated at the following rates percent compound interest.

Years.	5%	6%	7%	8%	10%
1	·9524	·9434	·9346	·9259	·9091
2	·9070	·8900	·8734	·8573	·8264
3	·8638	·8396	·8163	·7938	·7513
4	·8227	·7921	·7629	·7350	·6830
5	·7835	·7473	·7130	·6806	·6209
6	·7462	·7050	·6663	·6302	·5645
7	·7107	·6651	·6228	·5835	·5132
8	·6768	·6274	·5820	·5403	·4665
9	·6446	·5919	·5439	·5002	·4241
10	·6139	·5584	·5083	·4632	·3855
11	·5847	·5268	·4751	·4289	·3505
12	·5568	·4970	·4440	·3971	·3186
13	·5303	·4688	·4150	·3677	·2897
14	·5051	·4423	·3878	·3405	·2633
15	·4810	·4173	·3624	·3152	·2394
16	·4581	·3936	·3387	·2919	·2176
17	·4363	·3714	·3166	·2703	·1978
18	·4155	·3503	·2959	·2502	·1799
19	·3957	·3305	·2765	·2317	·1635
20	·3769	·3118	·2584	·2145	·1486
21	·3589	·2942	·2415	·1987	·1351
22	·3419	·2775	·2257	·1839	·1228
23	·3256	·2618	·2109	·1703	·1117
24	·3101	·2470	·1971	·1577	·1015
25	·2953	·2330	·1842	·1460	·0923
26	·2812	·2198	·1722	·1352	·0839
27	·2678	·2074	·1609	·1252	·0763
28	·2551	·1956	·1504	·1159	·0693
29	·2430	·1846	·1406	·1073	·0630
30	·2314	·1741	·1314	·0994	·0573
35	·1813	·1301	·0937	·0676	·0356
40	·1420	·0972	·0668	·0460	·0221
45	·1113	·0727	·0476	·0313	·0137
50	·0872	·0543	·0339	·0213	·0085

TABLE 15.

$$R_n \text{ or } \frac{I^n - 1}{i} \text{ or } \frac{(1+i)^n - 1}{i}$$

The amount of Re1 per year in n years accumulating at the following rates percent. Immediate annuity.

Years.	2½%	3%	3½%	4%	4½%
1	1·0000	1·0000	1·0000	1·0000	1·0000
2	2·0250	2·0300	2·0350	2·0400	2·0450
3	3·0756	3·0909	3·1062	3·1216	3·1370
4	4·1525	4·1836	4·2149	4·2465	4·2782
5	5·2563	5·3091	5·3625	5·4163	5·4707
6	6·3877	6·4684	6·5502	6·6330	6·7169
7	7·5474	7·6625	7·7794	7·8983	8·0192
8	8·7361	8·8923	9·0517	9·2142	9·3800
9	9·9545	10·1591	10·3685	10·5828	10·8021
10	11·2034	11·4639	11·7314	12·0061	12·2882
11	12·4835	12·8078	13·1420	13·4864	13·8412
12	13·7956	14·1920	14·6020	15·0258	15·4640
13	15·1404	15·6178	16·1130	16·6268	17·1599
14	16·5190	17·0863	17·6770	18·2919	18·9321
15	17·9319	18·5989	19·2957	20·0236	20·7841
16	19·3802	20·1569	20·9710	21·8245	22·7193
17	20·8647	21·7616	22·7050	23·6975	24·7417
18	22·3863	23·4144	24·4997	25·6454	26·8551
19	23·9460	25·1169	26·3572	27·6712	29·0636
20	25·5447	26·8704	28·2797	29·7781	31·3714
21	27·1833	28·6765	30·2695	31·9692	33·7831
22	28·8629	30·5368	32·3289	34·2480	36·3034
23	30·5844	32·4529	34·4604	36·6179	38·9370
24	32·3490	34·4265	36·6665	39·0826	41·6892
25	34·1578	36·4593	38·9499	41·6459	44·5652
26	36·0117	38·5530	41·3131	44·3117	47·5706
27	37·9120	40·7096	43·7591	47·0842	50·7113
28	39·8598	42·9309	46·2906	49·9676	53·9933
29	41·8563	45·2189	48·9108	52·9663	57·4230
30	43·9027	47·5754	51·6227	56·0849	61·0071
35	54·9282	60·4621	66·6740	73·6522	81·4966
40	67·4026	75·4013	84·5503	95·0255	107·0303
45	81·5161	92·7199	105·7817	121·0294	138·8500
50	97·4843	112·7969	130·9980	152·6671	178·5030

TABLE 15.—(*Contd.*)

$$R_n \text{ or } \frac{I^n - 1}{i} \text{ or } \frac{(1+i)^n - 1}{i}$$

The amount of Re1 per year in n years accumulating at the following rates percent. Immediate annuity.

Years.	5%	6%	7%	8%	10%
1	1·0000	1·0000	1·0000	1·0000	1·0000
2	2·0500	2·0600	2·0700	2·0800	2·1000
3	3·1525	3·1836	3·2149	3·2464	3·3100
4	4·3101	4·3746	4·4399	4·5061	4·6410
5	5·5256	5·6371	5·7507	5·8666	6·1051
6	6·8019	6·9753	7·1533	7·3359	7·7156
7	8·1420	8·3938	8·6540	8·9228	9·4872
8	9·5491	9·8975	10·2598	10·6366	11·4359
9	11·0266	11·4913	11·9780	12·4876	13·5795
10	12·5779	13·1808	13·8164	14·4866	15·9374
11	14·2068	14·9716	15·7836	16·6455	18·5312
12	15·9171	16·8699	17·8885	18·9771	21·3843
13	17·7130	18·8821	20·1406	21·4953	24·5227
14	19·5986	21·0151	22·5505	24·2149	27·9750
15	21·5786	23·2760	25·1290	27·1521	31·7725
16	23·6575	25·6725	27·8881	30·3243	35·9497
17	25·8404	28·2129	30·8402	33·7502	40·5447
18	28·1324	30·9057	33·9990	37·4502	45·5992
19	30·5390	33·7600	37·3790	41·4463	51·1591
20	33·0660	36·7856	40·9955	45·7620	57·2750
21	35·7193	39·9927	44·8652	50·4229	64·0025
22	38·5052	43·3923	49·0057	55·4568	71·4027
23	41·4305	46·9958	53·4361	60·8933	79·5430
24	44·5020	50·8156	58·1767	66·7648	88·4973
25	47·7271	54·8645	63·2490	73·1059	98·3471
26	51·1135	59·1564	68·6765	79·9544	109·1818
27	54·6691	63·7058	74·4838	87·3508	121·0999
28	58·4026	68·5281	80·6977	95·3388	134·2099
29	62,3227	73·6398	87·3465	103·9659	148·6309
30	66·4388	79·0582	94·4608	113·2832	164·4940
35	90·3203	111·4348	138·2369	172·3168	271·0244
40	120·7998	154·7620	199·6351	259·0565	442·5926
45	159·7002	212·7435	285·7493	386·5056	718·9048
50	209·3480	290·3359	406·5289	573·7701	1163·909

TABLE 16.

$$\frac{I^n - 1}{iI^n} \quad \text{or} \quad \frac{(1+i)^n - 1}{i(1+i)^n}$$

Present value of an immediate annuity of Re 1 per year for n years at the following rates percent.

Years.	2½%	3%	3½%	4%	4½%
1	0·9756	0·9709	0·9662	0·9615	0·9569
2	1·9274	1·9135	1·8997	1·8861	1·8727
3	2·8560	2·8286	2·8016	2·7751	2·7490
4	3·7620	3·7171	3·6731	3·6299	3·5875
5	4·6458	4·5797	4·5151	4·4518	4·3900
6	5·5081	5·4172	5·3286	5·2421	5·1579
7	6·3494	6·2303	6·1145	6·0021	5·8927
8	7·1701	7·0197	6·8740	6·7327	6·5959
9	7·9709	7·7861	7·6077	7·4353	7·2688
10	8·7521	8·5302	8·3166	8·1109	7·9127
11	9·5142	9·2526	9·0016	8·7605	8·5289
12	10·2578	9·9540	9·6633	9·3851	9·1186
13	10·9832	10·6350	10·3027	9·9856	9·6829
14	11·6909	11·2961	10·9205	10·5631	10·2228
15	12·3814	11·9379	11·5174	11·1184	10·7395
16	13·0550	12·5611	12·0941	11·6523	11·2340
17	13·7122	13·1661	12·6513	12·1657	11·7072
18	14·3534	13·7535	13·1897	12·6593	12·1600
19	14·9789	14·3238	13·7098	13·1339	12·5933
20	15·5892	14·8775	14·2124	13·5903	13·0079
21	16·1845	15·4150	14·6980	14·0292	13·4047
22	16·7654	15·9369	15·1671	14·4511	13·7844
23	17·3321	16·4436	15·6204	14·8568	14·1478
24	17·8850	16·9355	16·0584	15·2470	14·4955
25	18·4244	17·4131	16·4815	15·6221	14·8282
26	18·9506	17·8768	16·8904	15·9828	15·1466
27	19·4640	18·3270	17·2854	16·3296	15·4513
28	19·9649	18·7641	17·6670	16·6631	15·7429
29	20·4535	19·1884	18·0358	16·9837	16·0219
30	20·9303	19·6004	18·3920	17·2920	16·2889
35	23·1452	21·4872	20·0007	18·6646	17·4610
40	25·1028	23·1148	21·3551	19·7928	18·4016
45	26·8330	24·5187	22·4955	20·7200	19·1563
50	28·3623	25·7298	23·4556	21·4822	19·7620

TABLE 16.—(*Contd.*)

$$\frac{I^n - 1}{iI^n} \text{ or } \frac{(1+i)^n - 1}{i(1+i)^n}$$

Present value of an immediate annuity of Re1 per year for n years at the following rates percent.

Years.	5%	6%	7%	8%	10%
1	0·9524	0·9434	0·9346	0·9259	0·9091
2	1·8594	1·8334	1·8080	1·7833	1·7355
3	2·7232	2·6730	2·6243	2·5771	2·4869
4	3·5460	3·4651	3·3872	3·3121	3·1699
5	4·3295	4·2124	4·1002	3·9927	3·7908
6	5·0757	4·9173	4·7665	4·6229	4·3553
7	5·7864	5·5824	5·3893	5·2064	4·8684
8	6·4632	6·2098	5·9713	5·7466	5·3349
9	7·1078	6·8017	6·5152	6·2469	5·7590
10	7·7217	7·3601	7·0236	6·7101	6·1446
11	8·3064	7·8869	7·4987	7·1390	6·4951
12	8·8633	8·3838	7·9427	7·5361	6·8137
13	9·3936	8·8527	8·3577	7·9038	7·1034
14	9·8986	9·2950	8·7455	8·2442	7·3667
15	10·3797	9·7122	9·1079	8·5595	7·6061
16	10·8378	10·1059	9·4466	8·8514	7·8237
17	11·2741	10·4773	9·7632	9·1216	8·0216
18	11·6896	10·8276	10·0591	9·3719	8·2014
19	12·0853	11·1581	10·3356	9·6036	8·3649
20	12·4622	11·4699	10·5940	9·8181	8·5136
21	12·8212	11·7641	10·8355	10·0168	8·6487
22	13·1630	12·0416	11·0612	10·2007	8·7715
23	13·4886	12·3034	11·2722	10·3711	8·8832
24	13·7986	12·5504	11·4693	10·5288	8·9847
25	14·0939	12·7834	11·6536	10·6748	9·0770
26	14·3752	13·0032	11·8258	10·8100	9·1609
27	14·6430	13·2105	11·9867	10·9352	9·2372
28	14·8981	13·4062	12·1371	11·0511	9·3066
29	15·1411	13·5907	12·2777	11·1584	9·3696
30	15·3725	13·7648	12·4090	11·2578	9·4269
35	16·3742	14·4982	12·9477	11·6546	9·6442
40	17·1591	15·0463	13·3941	11·9246	9·7791
45	17·7741	15·4558	13·6055	12·1084	9·8628
50	18·2559	15·7619	13·8007	12·2335	9·9148

TABLE 17.

$$\frac{1}{\dfrac{i}{I^n - 1} + i'} \quad \text{or} \quad \frac{1}{\text{Sinking fund allotment}^* + \text{speculative interest}}$$

Present value of Re1 per year over n years, redemption of capital at $2\frac{1}{2}$%, speculative interest at the following rates percent.

Years.	4%	5%	6%	7%	8%
1	0·9615	0·9524	0·9434	0·9346	0·9259
2	1·8733	1·8388	1·8056	1·7736	1·7427
3	2·7387	2·6657	2·5965	2·5308	2·4683
4	3·5610	3·4386	3·3243	3·2173	3·1170
5	4·3432	4·1624	3·9961	3·8425	3·7003
6	5·0878	4·8414	4·6179	4·4140	4·2274
7	5·7973	5·4796	5·1949	4·9384	4·7060
8	6·4739	6·0802	5·7317	5·4210	5·1423
9	7·1196	6·6464	6·2322	5·8666	5·5415
10	7·7364	7·1809	6·6998	6·2791	5·9081
11	8·3260	7·6860	7·1375	6·6620	6·2459
12	8·8899	8·1641	7·5479	7·0182	6·5579
13	9·4297	8·6171	7·9335	7·3503	6·8471
14	9·9466	9·0468	8·2962	7·6607	7·1156
15	10·4421	9·4548	8·6381	7·9512	7·3656
16	10·9172	9·8426	8·9607	8·2238	7·5988
17	11·3730	10·2116	9·2655	8·4798	7·8169
18	11·8105	10·5630	9·5538	8·7207	8·0212
19	12·2308	10·8979	9·8270	8·9477	8·2128
20	12·6347	11·2174	10·0860	9·1619	8·3930
21	13·0230	11·5224	10·3319	9·3644	8·5626
22	13·3965	11·8138	10·5656	9·5560	8·7225
23	13·7558	12·0924	10·7879	9·7374	8·8734
24	14·1018	12·3590	10·9995	9·9095	9·0161
25	14·4350	12·6142	11·2012	10·0729	9·1511
26	14·7561	12·8586	11·3936	10·2282	9·2791
27	15·0655	13·0930	11·5772	10·3759	9·4005
28	15·3638	13·3177	11·7525	10·5166	9·5158
29	15·6516	13·5334	11·9202	10·6506	9·6254
30	15·9292	13·7405	12·0806	10·7785	9·7297
35	17·1805	14·6616	12·7868	11·3372	10·1827
40	18·2361	15·4235	13·3625	11·7874	10·5445
45	19·1323	16·0597	13·8375	12·1555	10·8381
50	19·8973	16·5953	14·2332	12·4598	11·0793

* Expressed as an annual percentage of the original capital.

TABLE 17.—(*Contd.*)

$$\frac{1}{\dfrac{i}{I^n-1}+i'} \quad \text{or} \quad \frac{1}{\text{Sinking fund allotment*}+\text{speculative interest}}$$

Present value of Re1 per year over n years, redemption of capital at $2\frac{1}{2}\%$, speculative interest at the following rates percent.

Years.	10%	12%	15%	20%	25%
1	0·9091	0·8929	0·8696	0·8333	0·8000
2	1·6840	1·6291	1·5532	1·4413	1·3446
3	2·3522	2·2465	2·1047	1·9043	1·7387
4	2·9341	2·7715	2·5587	2·2685	2·0374
5	3·4453	3·2232	2·9390	2·5625	2·2715
6	3·8979	3·6160	3·2621	2·8047	2·4597
7	4·3012	3·9605	3·5399	3·0076	2·6144
8	4·6627	4·2650	3·7812	3·1800	2·7437
9	4·9886	4·5360	3·9927	3·3283	2·8534
10	5·2838	4·7788	4·1796	3·4571	2·9476
11	5·5523	4·9974	4·3458	3·5701	3·0293
12	5·7975	5·1952	4·4946	3·6699	3·1009
13	6·0223	5·3749	4·6286	3·7587	3·1641
14	6·2291	5·5390	4·7498	3·8382	3·2202
15	6·4199	5·6894	4·8599	3·9098	3·2705
16	6·5964	5·8275	4·9603	3·9746	3·3157
17	6·7601	5·9549	5·0523	4·0334	3·3565
18	6·9123	6·0727	5·1369	4·0871	3·3936
19	7·0541	6·1820	5·2148	4·1363	3·4275
20	7·1866	6·2835	5·2869	4·1815	3·4584
21	7·3106	6·3781	5·3537	4·2232	3·4869
22	7·4268	6·4664	5·4158	4·2617	3·5131
23	7·5360	6·5489	5·4736	4·2974	3·5374
24	7·6387	6·6263	5·5275	4·3306	3·5598
25	7·7354	6·6990	5·5780	4·3616	3·5807
26	7·8266	6·7673	5·6253	4·3904	3·6001
27	7·9128	6·8317	5·6697	4·4174	3·6182
28	7·9944	6·8924	5·7114	4·4427	3·6352
29	8·0716	6·9497	5·7507	4·4665	3·6511
30	8·1448	7·0039	5·7878	4·4888	3·6660
35	8·4598	7·2356	5·9451	4·5828	3·7285
40	8·7081	7·4164	6·0666	4·6547	3·7759
45	8·9073	7·5694	6·1627	4·7110	3·8129
50	9·0696	7·6771	6·2399	4·7561	3·8423

* Expressed as an annual percentage of the original capital.

TABLE 17.—(*Contd.*)

$$\frac{1}{\dfrac{i}{I^n-1}+i'} \text{ or } \frac{1}{\text{Sinking fund allotment}^*+\text{speculative interest}}$$

Present value of Re1 per year over n years, redemption of capital at 3%, speculative interest at the following rates percent.

Years.	4%	5%	6%	7%	8%
1	0·9615	0·9524	0·9434	0·9346	0·9259
2	1·8775	1·8429	1·8096	1·7774	1·7464
3	2·7508	2·6772	2·6074	2·5411	2·4781
4	3·5839	3·4599	3·3442	2·2360	3·1345
5	4·3792	4·1954	4·0265	3·8706	3·7264
6	5·1388	4·8876	4·6599	4·4524	4·2626
7	5·8649	5·5400	5·2492	4·9874	4·7505
8	6·5593	6·1555	5·7986	5·4808	5·1960
9	7·2237	6·7370	6·3118	5·9370	5·6043
10	7·8597	7·2870	6·7921	6·3601	5·9798
11	8·4690	7·8078	7·2423	6·7532	6·3260
12	9·0529	8·3014	7·6651	7·1194	6·6462
13	9·6127	8·7697	8·0626	7·4610	6·9430
14	10·1496	9·2144	8·4369	7·7805	7·2188
15	10·6648	9·6370	8·7899	8·0797	7·4757
16	11·1594	10·0391	9·1232	8·3604	7·7154
17	11·6343	10·4218	9·4382	8·6242	7·9395
18	12·0906	10·7865	9·7363	8·8724	8·1494
19	12·5291	11·1341	10·0186	9·1063	8·3463
20	12·9507	11·4658	10·2864	9·3270	8·5313
21	13·3562	11·7825	10·5405	9·5355	8·7054
22	13·7462	12·0850	10·7820	9·7326	8·8694
23	14·1215	12·3741	11·0115	9·9193	9·0241
24	14·4828	12·6506	11·2300	10·0962	9·1703
25	14·8307	12·9152	11·4380	10·2640	9·3086
26	15·1657	13·1686	11·6363	10·4234	9·4395
27	15·4885	13·4113	11·8253	10·5748	9·5635
28	15·7995	13·6438	12·0058	10·7189	9·6812
29	16·0993	13·8668	12·1781	10·8560	9·7929
30	16·3883	14·0807	12·3427	10·9867	9·8991
35	17·6868	15·0287	13·0651	11·5554	10·3585
40	18·7750	15·8072	13·6496	12·0102	10·7224
45	19·6908	16·4514	14·1273	12·3785	11·0150
50	20·4643	16·9879	14·5211	12·6798	11·2530

* Expressed as an annual percentage of the original capital.

TABLE 17.—(*Contd.*)

$$\frac{1}{\dfrac{i}{I^n-1}+i'} \quad \text{or} \quad \frac{1}{\text{Sinking fund allotment*}+\text{speculative interest}}$$

Present value of Re1 per year over n years, redemption of capital at 3%, speculative interest at the following rates percent.

Years.	10%	12%	15%	20%	25%
1	0·9091	0·8929	0·8696	0·8333	0·8000
2	1·6874	1·6324	1·5562	1·4438	1·3466
3	2·3611	2·2546	2·1118	1·9101	1·7436
4	2·9496	2·7853	2·5705	2·2778	2·0449
5	3·4680	3·2430	2·9555	2·5750	2·2813
6	3·9278	3·6417	3·2830	2·8201	2·4716
7	4·3383	3·9919	3·5650	3·0257	2·6281
8	4·7068	4·3019	3·8102	3·2004	2·7590
9	5·0395	4·5780	4·0252	3·3508	2·8700
10	5·3410	4·8255	4·2153	3·4815	2·9653
11	5·6155	5·0485	4·3845	3·5961	3·0481
12	5·8664	5·2504	4·5359	3·6974	3·1205
13	6·0965	5·4339	4·6723	3·7875	3·1844
14	6·3081	5·6014	4·7956	3·8681	3·2412
15	6·5034	5·7548	4·9076	3·9406	3·2920
16	6·6840	5·8958	5·0097	4·0062	3·3377
17	6·8515	6·0258	5·1033	4·0658	3·3789
18	7·0073	6·1460	5·1892	4·1202	3·4164
19	7·1524	6·2573	5·2683	4·1699	3·4505
20	7·2878	6·3607	5·3414	4·2156	3·4817
21	7·4144	6·4570	5·4092	4·2576	3·5104
22	7·5331	6·5468	5·4720	4·2965	3·5367
23	7·6444	6·6347	5·5305	4·3325	3·5611
24	7·7491	6·7093	5·5851	4·3659	3·5836
25	7·8476	6·7830	5·6361	4·3970	3·6045
26	7·9404	6·8522	5·6838	4·4260	3·6240
27	8·0280	6·9173	5·7286	4·4531	3·6421
28	8·1107	6·9787	5·7706	4·4784	3·6591
29	8·1890	7·0366	5·8101	4·5022	3·6749
30	8·2631	7·0912	5·8473	4·5245	3·6898
35	8·5808	7·3239	6·0046	4·6181	3·7518
40	8·8291	7·5040	6·1251	4·6891	3·7985
45	9·0265	7·6461	6·2195	4·7442	3·8346
50	9·1856	7·7600	6·2946	4·7878	3·8630

* Expressed as an annual percentage of the original capital.

TABLE 17.—(*Contd.*)

$$\frac{1}{\dfrac{i}{I^n - 1} + i'} \quad \text{or} \quad \frac{1}{\text{Sinking fund allotment}^* + \text{speculative interest}}$$

Present value of Re1 per year over *n* years, redemption of capital at $3\frac{1}{2}$%, speculative interest at the following rates percent.

Years.	4%	5%	6%	7%	8%
1	0·9615	0·9524	0·9434	0·9346	0·9259
2	1·8818	1·8471	1·8136	1·7813	1·7501
3	2·7629	2·6886	2·6183	2·5515	2·4880
4	3·6068	3·4813	3·3642	3·2547	3·1521
5	4·4154	4·2287	4·0571	3·8989	3·7526
6	5·1903	4·9342	4·7022	4·4909	4·2980
7	5·9332	5·6008	5·3038	5·0368	4·7951
8	6·6455	6·2252	5·8659	5·5408	5·2500
9	7·3289	6·8285	6·3920	6·0078	5·6675
10	7·9846	7·3942	6·8851	6·4416	6·0518
11	8·6139	7·9307	7·3480	6·8451	6·4065
12	9·2180	8·4400	7·7831	7·2213	6·7347
13	9·7980	8·9237	8·1926	7·5723	7·0392
14	10·3551	9·3834	8·5785	7·9008	7·3222
15	10·8903	9·8208	8·9425	8·2082	7·5858
16	11·4045	10·2370	9·2864	8·4976	7·8318
17	11·8987	10·6334	9·6114	8·7688	8·0617
18	12·3737	11·0112	9·9190	9·0236	8·2770
19	12·8303	11·3713	10·2103	9·2644	8·4789
20	13·2694	11·7149	10·4865	9·4913	8·6684
21	13·6918	12·0429	10·7485	9·7050	8·8467
22	14·0980	12·3560	10·9972	9·9079	9·0145
23	14·4888	12·6552	11·2336	10·0990	9·1727
24	14·8648	12·9412	11·4583	10·2807	9·3220
25	15·2267	13·2146	11·6721	10·4526	9·4631
26	15·5750	13·4761	11·8757	10·6146	9·5964
27	15·9103	13·7264	12·0697	10·7701	9·7227
28	16·2331	13·9660	12·2545	10·9170	9·8423
29	16·5439	14·1954	12·4308	11·0558	9·9557
30	16·8431	14·4152	12·5990	11·1894	10·0633
35	18·1824	15·3850	13·3336	11·7647	10·5265
40	19·2949	16·1741	13·9223	12·2205	10·8900
45	20·2210	16·8199	14·3981	12·5865	11·1790
50	20·9935	17·3510	14·7855	12·8816	11·4111

* Expressed as an annual percentage of the original capital.

TABLE 17.—(*Contd.*)

$$\frac{1}{\frac{i}{I^n-1}+i'} \quad \text{or} \quad \frac{1}{\text{Sinking fund allotment}^*+\text{speculative interest}}$$

Present value of Re1 per year over n years, redemption of capital at $3\frac{1}{2}\%$, speculative interest at the following rates percent.

Years.	10%	12%	15%	20%	25%
1	0·9091	0·8929	0·8696	0·8333	0·8000
2	1·6909	1·6356	1·5591	1·4463	1·3488
3	2·3700	2·2628	2·1189	1·9160	1·7485
4	2·9651	2·7992	2·5823	2·2870	2·0523
5	3·4906	3·2628	2·9719	2·5874	2·2910
6	3·9578	3·6675	3·3039	2·8355	2·4834
7	4·3755	4·0234	3·5901	3·0437	2·6417
8	4·7511	4·3388	3·8391	3·2209	2·7741
9	5·0905	4·6201	4·0577	3·3733	2·8865
10	5·3984	4·8723	4·2510	3·5058	2·9829
11	5·6789	5·0996	4·4230	3·6220	3·0666
12	5·9353	5·3055	4·5770	3·7246	3·1399
13	6·1705	5·4926	4·7156	3·8159	3·2045
14	6·3869	5·6635	4·8410	3·8976	3·2619
15	6·5865	5·8199	4·9548	3·9710	3·3132
16	6·7712	5·9636	5·0586	4·0374	3·3593
17	6·9424	6·0960	5·1535	4·0976	3·4009
18	7·1014	6·2183	5·2406	4·1525	3·4386
19	7·2495	6·3315	5·3208	4·2027	3·4729
20	7·3876	6·4366	5·3949	4·2488	3·5043
21	7·5167	6·5344	5·4634	4·2912	3·5331
22	7·6375	6·6255	5·5269	4·3303	3·5596
23	7·7508	6·7106	5·5860	4·3665	3·5840
24	7·8571	6·7901	5·6410	4·4000	3·6066
25	7·9571	6·8646	5·6924	4·4312	3·6275
26	8·0512	6·9346	5·7404	4·4602	3·6469
27	8·1398	7·0002	5·7853	4·4873	3·6650
28	8·2235	7·0620	5·8274	4·5126	3·6818
29	8·3025	7·1202	5·8670	4·5363	3·6976
30	8·3772	7·1751	5·9042	4·5585	3·7123
35	8·6958	7·4075	6·0607	4·6512	3·7736
40	8·9424	7·5857	6·1794	4·7208	3·8193
45	9·1363	7·7248	6·2714	4·7743	3·8543
50	9·2908	7·8349	6·3438	4·8162	3·8815

* Expressed as an annual percentage of the original capital.

TABLE 17.—(*Contd.*)

$$\frac{1}{\dfrac{i}{I^n-1}+i'} \quad \text{or} \quad \frac{1}{\text{Sinking fund allotment*}+\text{speculative interest}}$$

Present value of Re1 per year over n years, redemption of capital at 4%, speculative interest at the following rates percent.

Years.	4%	5%	6%	7%	8%
1	0·9615	0·9524	0·9434	0·9346	0·9259
2	1·8861	1·8512	1·8175	1·7859	1·7538
3	2·7751	2·7002	2·6292	2·5618	2·4978
4	3·6299	3·5027	3·3842	3·2735	3·1697
5	4·4518	4·2621	4·0879	3·9273	3·7789
6	5·2421	4·9810	4·7447	4·5298	4·3335
7	6·0021	5·6622	5·3588	5·0865	4·8400
8	6·7327	6·3080	5·9337	5·6014	5·3043
9	7·4353	6·9208	6·4728	6·0794	5·7309
10	8·1109	7·5024	6·9788	6·5235	6·1240
11	8·7605	8·0548	7·4544	6·9377	6·4872
12	9·3851	8·5798	7·9019	7·3233	6·8235
13	9·9857	9·0790	8·3234	7·6839	7·1355
14	10·5631	9·5539	8·7208	8·0213	7·4256
15	11·1184	10·0059	9·0958	8·3374	7·6958
16	11·6523	10·4362	9·4500	8·6341	7·9479
17	12·1657	10·8462	9·7849	8·8128	8·1834
18	12·6593	11·2368	10·1017	9·1749	8·4038
19	13·1339	11·6092	10·4016	9·4216	8·6104
20	13·5903	11·9643	10·6858	9·6542	8·8042
21	14·0292	12·3031	10·9553	9·8736	8·9863
22	14·4511	12·6265	11·2109	10·0808	9·1576
23	14·8568	12·9351	11·4536	10·2765	9·3189
24	15·2470	13·2298	11·6840	10·4617	9·4709
25	15·6221	13·5113	11·9031	10·6369	9·6143
26	15·9828	13·7803	12·1113	10·8029	9·7497
27	16·3296	14·0374	12·3094	10·9602	9·8777
28	16·6631	14·2831	12·4980	11·1095	9·9987
29	16·9837	14·5180	12·6775	11·2511	10·1133
30	17·2920	14·7427	12·8485	11·3856	10·2218
35	18·6646	15·7289	13·5911	11·9650	10·6863
40	19·7928	16·5225	14·1797	12·4187	11·0469
45	20·7200	17·1637	14·6493	12·7775	11·3298
50	21·4822	17·6834	15·0263	13·0633	11·5540

* Expressed as an annual percentage of the original capital.

TABLE 17.—(*Concld.*)

$$\frac{1}{\dfrac{i}{I^n-1}+i'} \quad \text{or} \quad \frac{1}{\text{Sinking fund allotment*}+\text{speculative interest}}$$

Present value of Re1 per year over n years, redemption of capital at 4%, speculative interest at the following rates percent.

Years.	10%	12%	15%	20%	25%
1	0·9091	0·8929	0·8696	0·8333	0·8000
2	1·6944	1·6388	1·5620	1·4489	1·3510
3	2·3790	2·2709	2·1261	1·9218	1·7533
4	2·9807	2·8130	2·5941	2·2963	2·0598
5	3·5134	3·2827	2·9884	2·5999	2·3008
6	3·9878	3·6933	3·3249	2·8509	2·4952
7	4·4129	4·0550	3·6152	3·0618	2·6553
8	4·7955	4·3758	3·8681	3·2412	2·7892
9	5·1416	4·6622	4·0901	3·3957	2·9028
10	5·4558	4·9191	4·2865	3·5299	3·0004
11	5·7422	5·1507	4·4613	3·6477	3·0850
12	6·0041	5·3604	4·6178	3·7516	3·1590
13	6·2444	5·5511	4·7586	3·8440	3·2243
14	6·4654	5·7251	4·8859	3·9267	3·2823
15	6·6693	5·8844	5·0015	4·0009	3·3340
16	6·8578	6·0306	5·1067	4·0680	3·3804
17	7·0324	6·1653	5·2030	4·1288	3·4223
18	7·1946	6·2896	5·2912	4·1842	3·4603
19	7·3455	6·4046	5·3723	4·2348	3·4948
20	7·4861	6·5112	5·4472	4·2812	3·5263
21	7·6173	6·6103	5·5163	4·3238	3·5552
22	7·7400	6·7025	5·5804	4·3630	3·5817
23	7·8549	6·7884	5·6399	4·3993	3·6061
24	7·9626	6·8688	5·6952	4·4329	3·6286
25	8·0637	6·9438	5·7467	4·4640	3·6495
26	8·1588	7·0142	5·7948	4·4930	3·6688
27	8·2482	7·0802	5·8398	4·5200	3·6868
28	8·3324	7·1422	5·8819	4·5452	3·7035
29	8·4118	7·2005	5·9214	4·5687	3·7191
30	8·4868	7·2553	5·9585	4·5907	3·7337
35	8·8046	7·4863	6·1133	4·6821	3·7940
40	9·0479	7·6615	6·2296	4·7501	3·8384
45	9·2368	7·7965	6·3186	4·8016	3·8720
50	9·3852	7·9020	6·3877	4·8414	3·8979

* Expressed as an annual percentage of the original capital.

TABLE 18.

Number of years required for the following rates of dividend overplus to accumulate to 100% if invested at 2, 3, 4 and 5% compound interest.

Overplus = dividend rate *less* speculative rate.	Reinvested at			
	2%	3%	4%	5%
%	Nearest year.	Nearest year.	Nearest year.	Nearest year.
1	56	47	41	37
2	35	31	28	26
3	26	23	22	20
4	21	19	18	17
5	17	16	15	14
6	15	14	13	12
7	13	12	12	11
8	11	11	10	10
9	10	10	9	9
10	9	9	9	8
11	8	8	8	8
12	8	8	7	7
13	7	7	7	7
14	7	7	6	6
15	6	6	6	6